

**Muslim Science Teacher Perceptions of the  
Nature of Science and their Impact on  
Teaching in Secondary Schools**

**Thesis submitted in partial fulfilment for  
the degree of Doctor of Philosophy  
at the University of London**

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**November 1996**

## ACKNOWLEDGEMENTS

Many different people have contributed to the production of this thesis. In particular, I should like to thank:

My supervisor, Dr A. Turner, whose incessant support and valuable advice were always forthcoming.

Dr Ghazi Algosaibi (Saudi Arabian Ambassador to the Court of St. James), for his consistent encouragement and intellectual support.

Rosalind Greenbaum, whose proficiency in word processing substantially improved the presentation of the thesis.

Zeba, Nafisah, Adam and Amina for their unstinting support. I love all four dearly. This thesis is dedicated to them and to the rest of my family - especially my parents, Munawar Sultana and Mohammed Sadiq Butt, who gave me the opportunity in life to embark on and complete it.

## **ABSTRACT**

The aim of this thesis is to find out about the nature of science views held by British Muslim science teachers teaching in Muslim secondary schools, and whether or not these views have any impact on how they teach the National Curriculum.

In the course of the study the views of a sample of non-Muslim science teachers and Muslim teachers teaching in state schools were elicited. The instrument used was the philosophy of science questionnaire based on systemic networks developed by Koulaidis and Ogborn (1989). The results were processed on the SPSS (Statistical Package for Social Sciences) database, and followed by interview with a sample of Muslim science teachers and classroom observations of some selected lessons.

The central finding was that the differences between Muslim teachers (in my sample) in their perceptions of science were not sufficiently clear to merit categorisation in an absolute sense. Predominantly, teachers (both Muslims and non-Muslims in my sample) tended to hold eclectic or mixed views about the nature of science, adhering to a diversity of elements taken from different philosophical positions.

For Muslim science teachers teaching in Muslim schools, the teaching of science was driven by the principle of glorifying the Creator. In one sense, the science was taken as read, in that the focus of science teachers was not to explore how scientific knowledge was gained or to question its validity, but to display the authority of the Quran and its predictive power.

Finally, some recommendations are made for improving the awareness amongst Muslim science teachers of nature of science issues. Further research that needs to be conducted in this area is also discussed.



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## INTRODUCTION

From the point of view of the global history of science, the Islamic sciences stood for some seven centuries as the most developed among the sciences cultivated in the different civilisations. They influenced the sciences of India and China as well as those of the West. They were only eclipsed in the West with the advent of the Renaissance and the Scientific Revolution, which made use of the material of science in the Islamic world. (It ought to be said, however, that for the first three hundred years of modern science in the West, there was a great deal of recognition of knowledge of higher orders of knowledge' among practitioners of science. Many 'scientists' were in Holy Orders and were concerned to glorify God in their science).

Islam was able to create an educational system and a scientific tradition which produced knowledge of the world of nature within a world-view dominated by the Transcendent as described in the Quranic revelation. There is, therefore, an inherent tension between the Islamic contextualisation of science and that of a modern, secular science divorced from knowledge of a higher order and agnostic about the idea of a unity which pervades the cosmos.

This tension is periodically manifested within intellectual circles deliberating over how best to integrate National Curriculum demands and Faith requirements. In my experience, however, most Muslim science teachers do not perceive such a tension. They believe that Quranic verses can readily be quoted in cementing the relationship between National Curriculum statements and faith requirements. But in the peculiar interpretation of their faith, however, I see cause for concern, a concern which has generated the central research questions (referred to later) of this thesis.

This position should be understood in the context of the growth of the Muslim faith in the UK (two million Muslims from 33 different ethnic backgrounds according to 1996 Islamic

Party of Britain statistics), with an increasing number of people entering and growing up in the UK within a Muslim faith. Conversions to Islam at the Islamic Cultural Centre (Regents Park Mosque) are now commonplace. All this is part of a growing tension between the established Church, the reality of a largely non-faith UK society and the legitimate needs of all sections of a pluralist society of which Islam is a part. The need by Muslims to come to terms with this tension is both a social and intellectual imperative.

Public ignorance about Islam does not help, of course, in bridge-building endeavours. A MORI poll commissioned by the London-based Iqra Trust in December 1990 revealed widespread ignorance about Islam across the UK. Four out of five people (85%) questioned about their knowledge of and attitudes to Islam admitted that they knew nothing or only a little about Islam. Almost half (46%) said they knew nothing though they had heard of the religion.

The tension outlined has affected the teaching of science in Muslim Schools, underlining the urgency for the growing number of Muslim Schools and their dilemma in meeting the National Curriculum while being true to their faith. Within this tension is another tension related to differences of interpretation and perception of the Quran and science amongst Muslim scholars, referred to later in the thesis.

Soon after the first version of the National Curriculum Science Orders appeared in 1988, Muslim Schools began deliberating how best to incorporate the attainment targets and programmes of study in the context of the ideological underpinnings of the Muslim faith.

Under the aegis of the Association of Muslim Schools (AMS), an umbrella organisation linking Muslim Schools through a common approach and educational agenda, programmes of implementation of National Curriculum Science Orders have been developed.

Concurrently, applications for Voluntary Aided Status (VAS) were made on two occasions by the Islamiyya School in Brent and, most recently, on one occasion by Feversham College, Bradford. All applications were met with DES, DFE and DFEE rejections.

Despite these discouraging setbacks Muslim Schools, through the AMS, are labouring at producing a comprehensive framework for science education which aims to fulfil National Curriculum requirements as well as catering for the theological-ideological sensitivities of the Muslim faith. In fact it was the old Attainment Target 17 - The Nature of Science - which forced thinking on this issue (DES, 1991).

The National Curriculum viewed as a characteristic tension of a pluralist society presents a dilemma for absolutist Muslim pedagogues. Tension therefore exists between the traditional Islamic view and the new perspective required in working within the framework of the National Curriculum.

The absolutist stance links both Islamic education and the Islamic sciences in the most intimate manner to the principles of the Islamic revelation and the spirit of the Quran. The Quran contains, according to the traditional Islamic perspective, the roots of all knowledge but not of course its details (as is contended by some apologists who would make the Divine Book a text book of science in the modern sense of the word).

The Quran ('the recitation'), is also referred to as 'the discernment', viewed as the supreme instrument of knowledge whereby truth is distinguished from falsehood. It is also 'the guidance', for it is believed to contain not only moral guidance but educational guidance - guidance which educates the whole being of Man in the most profound and complete sense. Hence it can be



appreciated why the Quran plays such a pivotal role for many Muslim curriculum conceivers, designers and implementors.

The AMS Curriculum Development Committee came to the conclusion in 1991 (when a National science curriculum based on 17 attainment targets was being promoted for implementation) that the most effective way to incorporate Islamic elements was through the Nature of Science theme - the old AT 17. There were, thus, sound educational reasons for teaching the nature of science as well as legal and moral reasons.

In the preamble to the programmes of study (POS) for KS3 the NC document (DES, 1991) states: 'To communicate, to apply and to investigate scientific and technological knowledge and ideas, and to understand the history of scientific ideas, are essential elements of a developing experience of science'. It goes on to state; 'Pupils should be given opportunities to develop knowledge and understanding of how scientific ideas change through time. They should study the development of some important ideas in science'.

Later, in the preamble to the POS for KS4, the NC includes the statement: 'Pupils should be given opportunities to ..... consider the power and limitations of science in addressing the industrial, social and environmental issues and some of the ethical dilemmas involved', and ..... consider ways in which scientific ideas may be affected by the social and historical contexts in which they develop, and how these contexts may affect whether or not the ideas are accepted'.

The AMS attempted to incorporate in their curriculum the ideas expressed in the old AT 17 (DES, 1991) ('Pupils should develop their knowledge and understanding of the ways in which scientific ideas change through time, and how the nature of these ideas and the uses to which they are put are affected by the social, moral, spiritual and cultural contexts in which they

are developed. In doing so, they should begin to recognise that, while science is an important way of thinking about experience, it is not the only way').

It was understood that these general statements indicated that these are areas which Muslim science teachers must teach and which Muslim students are expected to experience, though they are not part of the national assessment programme.

The following problems were encountered in the implementation of such programmes, some of which became the basis of the present research programme:

- Muslim science teachers' lack of understanding of the nature of science themes
- a sizeable number of Muslim science teachers teaching in Muslim Schools having a non-British educational background
- teachers never having encountered even an elementary study of the philosophy of science in their undergraduate or postgraduate courses
- varying perceptions of how 'fundamental' one needs to be in incorporating Islamic input in nature of science work
- the tendency of some science teachers to take the Quran as a Book of Science
- the prevalent belief that the Quran contains the seeds of scientific theories known and those yet to be developed/discovered.

It was important, therefore, to conduct research into Muslim science teacher perceptions of the nature of science and their impact on NC delivery. As a preliminary to this, it was considered equally important to review developments in the Islamic philosophy of science, and make a comparison with developments in occidental philosophy of science. The assumptions here are likely (ultimately) to influence attitudes towards science teaching. Hence we progress first towards such a review.

## **CHAPTER 1**

### **THE PERCEPTION OF SCIENCE IN THE WESTERN AND ISLAMIC WORLDS**

#### **1. The Western Perception of Science**

##### **1.1 Setting the context**

##### **1.2 The Popperian view of science**

##### **1.3 Kuhn and ‘The Structure of Scientific Revolutions’**

##### **1.4 From Knowledge to Wisdom: A revolution in the aims and methods of science**

##### **1.5 A critique of modern science**

#### **2. The Islamic Perception of Science**

##### **2.1 Islam: a world-view and a civilization**

##### **2.2 Science from the Islamic perspective**

##### **2.3 Islamic science: the contemporary debate**

#### **3. Western Science and Islamic Science Juxtaposed**

##### **3.1 Comparing intellectual traditions**

##### **3.2 A comparison between Western science and Islamic science (Sardar’s attempt)**

##### **3.3 Retabulation of Sardar’s attempt with further explanatory commentary and criticisms**

## 1. THE WESTERN PERCEPTION OF SCIENCE

### 1.1 Setting the context

“If what we are discussing were a point of law or of the humanities, in which neither true nor false exists, one might trust in subtlety of mind and readiness of tongue and in the greater experience of the writers, and expect him who excelled in those things to make his reasoning most plausible, and one might judge it to be the best. But in the natural sciences, whose conclusions are true and necessary and have nothing to do with human will, one must take care not to place oneself in the defence of error; for here a thousand Demostheneses and a thousand Aristotles would be left in the lurch by every mediocre wit who happened to hit upon the truth for himself.”

GALILEO GALILEI

(Quoted in Easlea, 1973, p.1)

## A DIALOGUE CONCERNING THE TWO CHIEF WORLD SYSTEMS.

The above kind of attitude towards the scientific enterprise - its putative objectivity, value neutrality and unilateral progression towards the truth - still persists in some intellectual spheres and academic circles as well as in public minds generally. It may come in the form of sophisticated argumentation, the complexity of which may immunise it from logical criticism, or in the form of a hazy and incoherent idea. Whatever the form of its belief and expression, this type of attitude has had a profound and damaging influence upon the academic domains of science, technology, scholarship and education.

This attitude towards science has been adapted into a sophisticated armoury of philosophical argumentation. It is the context for much of the science practised today and it has also penetrated both the theoretical and practical domains of science education.

Stated in the format of a philosophical thesis, it has been labelled by Nicholas Maxwell as the philosophy of knowledge (Maxwell, 1984). Its central tenet is that the proper aim for academic/rational inquiry is to acquire knowledge about the world, objective knowledge of truth. The ultimate aim is social progress, welfare and enlightenment, but in order to achieve this one must dissociate intellectual problems from humanitarian problems. Only thus can the problems of humanity be efficiently addressed and effectively solved.

Aspects of this idea were prevalent in the works of the ancient Greeks - Plato, Aristotle, Euclid, Archimedes. It is with the rise of modern science, however, in the sixteenth and seventeenth centuries, that this kind of philosophy of science began to shape its identity as well as its destiny. It had a profound intellectual impact upon, as well as being practised and further developed by, the illustrious Western philosopher-scientists such as Copernicus, Kepler, Galileo, Descartes, Huygen, Hooke, Boyle, Leibniz and above all Newton in his *Principia Mathematica* of 1687.

Even before Newton, Francis Bacon gave a powerful and lucid expression of observation and the experimental basis of results. Speculations, prejudices and the myths of philosophers had no part to play in science.

This bifurcation of 'objective' scientific knowledge on the one hand, and 'subjective' values and experiences on the other, was intellectualized by Descartes in the seventeenth century into the mechanistic world-view of Cartesian dualism. An intellectual split in rational inquiry was engendered when the objective world of fact, matter and physical reality was dissociated from the subjective world of mind, consciousness, personal experience and value. This type of mechanistic Enlightenment thinking where scientific reason reigned supreme, was to exercise a profound impact upon the minds of scientists and philosophers for the subsequent two centuries.

Modern science is an intellectual legacy of the values of the Enlightenment. Enlightenment thinkers stressed the importance of acquiring knowledge of man, society and history in addition to Nature. This, they believed, would lead to social progress and human enlightenment. To this end, figures such as Montesquieu, Voltaire, Diderot and Hume worked for the establishment of a new discipline called 'moral philosophy', to counterbalance the natural philosophy expounded by Newton.

In the philosophy of the Enlightenment, reason took on a central and quintessential role. Reason, as expounded by the seventeenth century rationalists such as Descartes, Leibniz, Hobbes and Spinoza, was incontrovertible, having unlimited power and absolute certainty. It effectively replaced the Christian God, dealing a near fatal blow to institutionalized Christianity. It became the sole arbiter of human thought and action, norms and values, taking on a central epistemological function. So much so that, rather than sounding the death knell for Enlightenment epistemology, the sceptical arguments of Hume served merely to assign a negative function to reason - that of establishing falsity to some claims to knowledge.

The Rationalist Enlightenment movement associated with figures such as Boyle, Voltaire, Diderot, Condorcet, Hume and Kant, gave rise in its wake to a counter movement - Romanticism, associated with figures such as Vico, Rousseau, Goethe, Beethoven, Blake, Wordsworth and Tolstoy.

The rationalism of the Enlightenment upheld:

anti-authoritarianism,

scepticism,

value of reason,

objectivity,

method,

logic,

evidence and

pursuit of impersonal, progressive factual knowledge.

It was suspicious of imagination, inner experience, personal feelings and desire, instinct and inspiration, self expression. Romanticism, however, upheld:

imagination,

inner experience,

personal feelings and desires,

instinct,

inspiration and

self expression,

rejecting rationalist values of objectivity, logic, reason and scepticism. This led to a severe intellectual split between rationalism on the one hand, with its influence on science, technology, scholarship and much of education and romanticism on the other, with its influence on literature, drama, art, music, and much of politics and religion. Such a schism generated acute problems for subsequent Western philosophers of science and they have persistently defied adequate solution. The debate essentially revolves around the central question of the demarcation between science and non-science. I describe below briefly, the intellectual endeavours of three twentieth century philosophers of science - Karl Popper, Thomas Kuhn and Nicholas Maxwell. (Analysis of a number of philosophy of science positions, particularly from the sociology of science perspective, has been carried out in Chapter 2.)

## 1.2 The Popperian view of science

Popper began with the problem of induction. He noted first that some theories typically

contain universal statements of the form, for example, 'all bodies attract each other with a force (for any two bodies) proportional to the product of the two masses and inversely proportional to the square of their distance apart' (Popper, 1963). This meant that, in general, theories cannot be induced from observed facts: that since no one has ever observed the cited universal statement to be the case, it can only have been imaginatively hypothesized to be part of a theory. Furthermore, we note that the carrying out of a finite number of successful tests can never prove such a theory to be true. There can be no guarantee that the next test, performed at a different time, possibly at a different place on the earth's surface, with possibly greater experimental accuracy than achieved in former tests, will not produce disagreement between predictions made from the theory and the result of the experiment. If and when such contradictory experimental results are observed, scientific revolutions follow. As a case in point, despite the hitherto overwhelmingly large number of observations and experiments in favour of fundamental principles proposed by Newton and his successors, the result of the Michelson-Morley experiment showed quite conclusively that one or more of these principles were false (Popper, 1963). The Einsteinian revolution followed.

Such considerations enabled Popper to set up demarcation criteria to distinguish between scientific and non-scientific theories as well as criteria to distinguish between scientists and pseudo-scientists. Popper's central thesis is basically enshrined in a declaration and a statement. He declares that it is a mistake to suppose that the essential feature distinguishing a scientific from a non-scientific theory is that the former is empirically verifiable. On the contrary, scientific theories, as opposed to non-scientific, are in principle not capable of empirical verification, but rather of empirical falsification. It is falsifiability, not verifiability, says Popper, 'that is to be taken as a criterion of demarcation' between scientific and non-scientific (or pseudo-scientific) theories (Popper, 1963).



Popper's statement comes in the form of 'the principle of empiricism which asserts that in science, only observation and experiment may decide upon the acceptance or rejection of scientific statements, including laws and theories' (Popper, 1963). The declaration of falsifiability as a distinguishing criterion, together with the principle of empiricism which endorses empirical refutation of scientific theories, constitute the intellectual backbone of Popper's philosophy of science thesis.

How is it possible, according to this view, to distinguish scientists from pseudo-scientists? Popper declares: 'Those among us who are unwilling to expose their ideas to the hazard of refutation do not take part in the scientific game'. The scientific method of research 'is not to defend [our present conjectures] in order to prove how right we were. On the contrary, we try to overthrow them. Using all the weapons of our logical, mathematical and technical armoury, we try to prove that our anticipations were false - in order to put forward in their stead new unjustified and unjustifiable anticipations, new "rash and premature prejudices" (Popper, 1963).

This Popperian hypothetico-deductive model of science with the emphasis on falsifiability is, in my judgement, a superficially attractive one. How a scientist arrives at a particular theory is a matter only of psychological interest; there are no hard and fast set of rules and procedures for making discoveries and ensuring new insights. As envisaged by Popper: 'The initial stage, the act of conceiving or inventing a theory seems to me neither to call for logical analysis, nor to be susceptible to it. The question of how it happens... may be of great interest to empirical psychology; but it is irrelevant to the logical analysis of scientific knowledge. The latter is concerned only... with questions of justification or validity' (Popper, 1963). The point is that once a theory has been publicised, questions of method of conception aside, the scientist has exposed his hypotheses to objective evaluation. Subjective factors undoubtedly play an important role in the conception of theories but they play none whatsoever in their evaluation. This leads

us to the distinction between the context of discovery, where subjective and value-laden concepts can freely play a part, and the context of justification, where only objective and value-free conceptual and methodological analyses should exist. According to Popper, of course, the latter context - that of justification - is epitomised by his principle of empiricism referred to earlier. (I criticise Popper's conception of the philosophy of science in Chapter 2.)

### 1.3 Kuhn and 'The Structure of Scientific Revolutions'

In 1962 Kuhn launched his radical and controversial attack upon the then prevalent 'conventional wisdom' that science progresses cumulatively towards an ever-greater understanding of physical reality, step by step, guided by logic and the appeal to a theory-independent empirical base (Kuhn, 1966). The attack was also aimed at Popper's advice to scientists to subject their theories to ever more stringent tests and ruthlessly reject them as soon as disagreement occurs between their theories and the accepted background knowledge.

Kuhn asserts that 'no process yet disclosed by the historical study of scientific development at all resembles the methodological stereotype of falsification by direct comparison with nature'. 'On the contrary,' Kuhn writes, 'it is just the incompleteness and imperfection of the existing data-theory fit that, at any time, define many of the puzzles that characterise normal science. If any and every failure to fit were ground for theory rejection all theories ought to be rejected at all times' (Kuhn, 1966).

This attack upon Popper's methodological and conceptual base of his falsifiability thesis merits further examination within the context of Kuhn's main thesis.

'Normal science', Kuhn claims, is to be sharply distinguished from those periods of scientific practice which constitute 'scientific revolutions' (Kuhn, 1966). It consists of articulation and further elaboration of the paradigm to which the scientific community is committed. However difficult the key concept of 'paradigm' is to define, Kuhn emphasizes that paradigms are readily revealed in scientists' 'textbooks, lectures and laboratory exercises' and that scientists can and do 'agree in their identification of a paradigm without agreeing on, or even attempting to produce, a full interpretation or rationalization of it' (Kuhn, 1966). Kuhn gives several partial definitions of the concept. He tells us, for example, that the paradigm must be seen as 'prior to the various concepts, laws, theories and points of view that may be abstracted from it', that it consists of a 'strong network of commitments - conceptual, theoretical, instrumental and methodological', thus permitting 'selection, evaluation and criticism', and that it is 'the source of the methods, problem-field and standards of solution accepted by any mature scientific community at any given time' (Kuhn, 1966).

Normal science is predicated on the assumption that the scientific community knows what the world is like, and is a 'strenuous and devoted attempt to force nature into the conceptual boxes supplied by the paradigm' (Kuhn, 1966). For Kuhn, the whole point of normal science is that the fit between the paradigm and reality is never exact, and it is this mismatch which supplies scientists with 'puzzles' for solution. Thus, all science puzzle-solving exercises fall within the conceptual and methodological paradigmatic framework so that 'failure to achieve a solution discredits only the scientist and not the theory' (Kuhn, 1966).

The history of science does show that at least on some occasions scientists have achieved success by behaving not as Popperian falsificationists but as 'Kuhnian' scientists. A case in point is the development of Newtonian theory. The paradigm here entails general commitment to the Newtonian concepts of space, time and matter, Newton's three laws of motion, and the

law of universal gravitation. The significant question was whether this paradigm could be further developed and articulated so as to resolve all the numerous puzzles arising from the mismatch between the paradigm itself and reality. As Kuhn has pointed out, the mismatch did not mean rejection of the paradigm. On the contrary, it was the incentive to develop the paradigm further - the disagreement with observation was the grist for its intellectual mill. Although Newton assumed that the earth's mass acted on a body as if all the mass were situated at the centre of the earth, it was some time before he could justify this mathematically. Initially the lunar calculations did not correspond to Newton's expectations but he later found that the earth's radius had not been accurately determined. Strange behaviour of Jupiter's moons did not mean the falsification of Newton's theory but rather information on the velocity of light. In the 19th century the anomalous movements of the newly discovered planet, Uranus, were not in accord with predictions from Newton's theory. Rather than instant falsification, the correctness of Newtonian theory was taken for granted and theoretical astronomers used the theory to predict and locate the position of a hitherto unknown planet responsible for the anomalous behaviour of Uranus. Thus Neptune was discovered. Venus was discovered in a similar fashion, the planetary misbehaviour of Mercury giving rise to predictions for the existence of another planet. A more recent and striking example is the discovery in August 1967 of pulsars, the most powerful and energetic objects in the universe. Describing the process of discovery within the conceptual framework of Kuhnian philosophy of science, Barry Barnes says that it was

“a process of cognitive change, initially within a small group of scientists. This is the typical pattern. However clear nature's communications might be, they are not encoded in language: nature does not describe itself. It is we who give meaning to her messages by determining how they should be fitted into existing concepts and beliefs, and how far our existing concepts and beliefs should be modified and extended to accommodate them. Another way of putting this is to say that there is no relevant difference between 'theoretical' and 'factual' concepts in science: both kinds of concepts are now inventions - 'star' and 'pulsar' as much as 'phlogiston' and 'oxygen'. And from this it follows that to corresponding entities of either kind involves processes of cognitive orientation.” (Barnes, 1982, p.44)

There comes a time, however, when a paradigm, having served its useful life, becomes intellectually redundant. Thus, in the first half of the 20th century the conceptual foundations of the Newtonian paradigm were irreparably shattered and replaced by altogether different foundations because of Einstein's general and special theories of relativity. Such a scientific revolution, according to Kuhn, will not happen simply because of a mismatch between theory and experiment. For defenders of a paradigm 'will devise numerous articulations and ad hoc modifications of their theory in order to eliminate any apparent conflict' (Kuhn, 1966). However, articulation of any paradigm may well lead to a crisis if there is a persistent failure of the puzzles of normal science to fit within the paradigmatic framework. In this crisis state, Kuhn tells us, a few scientists, usually the younger ones who are less emotionally committed to the existing paradigm than the senior scientists, will lose faith in that paradigm and consider alternative ones. The intellectual signs of a crisis state are, in Kuhn's own words, 'the expression of explicit discontent, the recourse to philosophy and to debate over fundamentals; all these are symptoms of a transition from normal to extraordinary research'. Also, writes Kuhn, 'the normal-scientific tradition that emerges from a scientific revolution is not only incompatible but often actually incommensurable with that which has gone before' (Kuhn, 1966).

According to Kuhn, the most fundamental aspect of incommensurability between competing paradigms is that the proponents of competing paradigms practise their trades in different worlds; they see different things when they look from the same point in the same direction. Thus, whereas when Aristotle looked at a swinging stone he saw constrained fall, Galileo saw a pendulum. Since the transition from one paradigm to another is 'a transition between incommensurables' it cannot be made stepwise or logically but, like the gestalt switch, it must occur all at once or not at all. Once a scientist has undergone this change of world-view to a new paradigm he attempts to convert the entire profession or the relevant professional subgroup to his way of seeing the world.

Thus, Kuhn demolished the putative objectivity and value-neutrality of science. According to him, there are not objective criteria by which the revolutionary scientist can show his colleagues committed to a different paradigm the error of their ways. Experimental results, logic and the techniques of persuasive argumentation are the deciding factors, the latter being apparently necessary since the issue of paradigm choice can never be unequivocally settled by logic and experiment alone.

All this is a far cry from Popper's earlier version of the hypothetico-deductive model of scientific progress in which stringent experimental testing must be carried out by open-minded, reasonable men, rationally evaluating their theories against all available experimental results. We now have consensus opinion produced by revolution, psychological conversion and rhetorical persuasion. The question remains - in what sense, if any, can science be said to be a search for truth, an intellectual enterprise in which all statements are subjected to rational evaluation, in which objective criteria automatically eliminate the influence of subjective elements? Nicholas Maxwell claims he has the frameworks of an answer.

#### 1.4 From Knowledge to Wisdom: A revolution in the aims and methods of science

Nicholas Maxwell argues for the need to put into practice a 'profound and comprehensive intellectual revolution, affecting to a greater or lesser extent all branches of scientific and technological research, scholarship and education' (Maxwell, 1984). Such a revolution he pointedly emphasizes, is not to be a change in paradigm in the Kuhnian sense but a radical change in the overall aims and methods of academic inquiry.

Maxwell's central claim is that during the last 400 years or so, with the gradual decline in influence of Christian thought in the universities, a peculiar conception of intellectual inquiry

- which he calls the philosophy of knowledge - has progressively become the dominant creed. It exercises a profound and penetrating influence over virtually all aspects of science, scholarship, technological research and education. The whole intellectual/institutional structure of the western world academic enterprise is built upon this intellectual foundation. 'And it is not just science, scholarship and education that are influenced by the philosophy of knowledge: through these the philosophy of knowledge exercises its influence, to a greater or lesser extent, over almost every aspect of our personal and social lives. Our very psyches, the way personal thought, feeling, desire and action tend to be interrelated, are affected by the prevalence of the philosophy of knowledge' (Maxwell, 1984).

Thus, for Maxwell, science as it is practised today has an all-consuming importance. Its epistemological success has led it to undeniable and remarkable intellectual and material achievements. This 'success', however, has been gained at paying a very heavy social price: the bifurcation of the personal and social world from the intellectual and academic; the segregation of knowledge and values. Maxwell writes:

"Inquiry as at present constituted (pursued in accordance with the philosophy of knowledge)... actually intensifies the gulf between personal and public worlds, in that it demands, as we shall see, that a decisive gulf be maintained between personal feelings and values on the one hand, and public, objective facts and knowledge on the other hand." (Maxwell, 1984, p.7)

According to Maxwell, the paradigmatic core of the philosophy of knowledge is standard empiricism, epitomized by Popper's principle of empiricism which states that 'in science, only observation and experiment may decide upon the acceptance or rejection of scientific statements, including laws and theories' (Popper, 1963, p.54). For Maxwell, this central tenet of standard empiricism is fundamentally flawed, at best intellectually naive and at worst socially disastrous. This is so because Popper's thesis requires a sharp distinction to be drawn between the context

of discovery and the context of justification. The context of discovery is where extra-scientific, personal, social and evaluative factors are allowed to influence scientists and academics in their choice of research aims and problems. In the context of justification, on the other hand, only the verification, corroboration or assessment of results is permitted as this is the context of the appraisal of theories or results from the standpoint of truth. To this end, one aim only must be taken into account - to discover truth, authentic, objective knowledge of fact. For the proponents of the philosophy of knowledge this distinction is essential claims Maxwell, if academic inquiry is to retain its rationality, objectivity and intellectual integrity.

Maxwell challenges the philosophy of knowledge in that very domain of inquiry where it would seem the most defensible - physics pursued for its own sake. He argues that the pursuit of knowledge in the physical sciences cannot be dissociated from the pursuit of understanding, from the problematic presupposition that the universe is, in some way, comprehensible. He describes how standard empiricism has failed to solve the practical and theoretical problem of induction, its failure to provide a rationale for preferring simple to complex theories in physics as well as an adequate specification of what simplicity is, its failure to provide a rationale for the acceptance and rejection of theories in the light of experimental results, and a failure to explain how it can be possible for theoretical physics to make progress.

So what is Maxwell's alternative to the philosophy of knowledge?

"The philosophy of wisdom is designed to overcome the fundamental and profoundly damaging defects of rationality inherent in the philosophy of knowledge. It differs radically from the philosophy of knowledge. All aspects of inquiry, all intellectual disciplines and the way these are related to each other and to the rest of society, are affected as we move from the philosophy of knowledge to the philosophy of wisdom. There is, however, nothing arbitrary about the basic principles of the philosophy of wisdom. These principles, as set out below, are necessarily what they are in order that the basic objective may be achieved: *a kind of inquiry that is devoted, in a genuinely rational way, to enabling people to realize what is of most value to them in life.*" (My italics.) (Maxwell, 1984, p.65)



Thus, for Maxwell, it is the pursuit of personal and social values in life, intellectualized and institutionalized by the philosophy of wisdom, the enhancement of which should be the primary aim of the academic enterprise.

Maxwell argues that rational inquiry pursued in accordance with the philosophy of knowledge devotes itself, in the first instance, to achieving the purely intellectual aim of acquiring objective knowledge of truth. This is dissociated from life and its problems with the hope (and expectation) that knowledge thus obtained may subsequently be applied to helping us solve our problems of living. The philosophy of wisdom, however, is designed to give absolute intellectual priority to our life and its problems, to help us rationally realize what is of value to us in life. The search for knowledge and understanding is rationally subordinated to the intellectually more fundamental search for value in life - problems of knowledge being rationally subordinated to problems of living, natural science being rationally subordinated to social inquiry (Fig. 1.1).

To achieve the objectives of the philosophy of wisdom, believes Maxwell, we must have faith in reason. Not in the authoritarian conception of reason as a set of rules which deliver indubitable, unchallengeable decisions to us, but as an intellectual partner to help us rationally decide what is of value to us. He thus mocks those who, in the twentieth century, claim that reason has no place in science (Paul Feyerabend in particular), asserting that it is not reason which is or should be under attack but rather a particular kind of irrationality (the philosophy of knowledge) which masquerades as reason.

Reason, according to Maxwell's thesis, should be devoted to the enhancement of wisdom, the latter being defined (by Maxwell) as 'the desire, the active endeavour, and the capacity to discover and achieve what is desirable and of value in life, both for oneself and for others'.

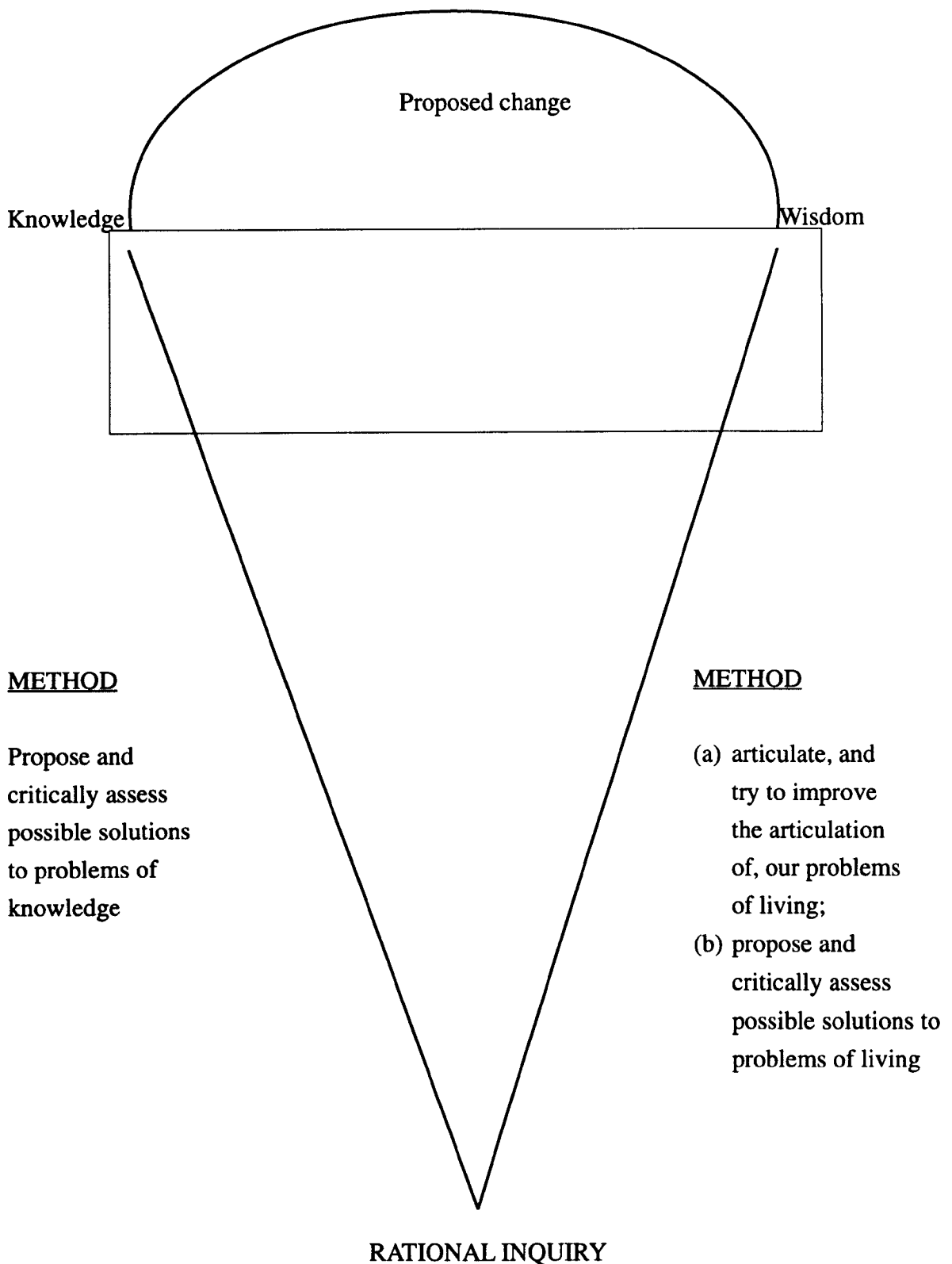


Figure 1.1 Maxwell's proposed change in the aims and methods of inquiry (Maxwell, 1984, p.82)

We have thus come a long way on this intellectual odyssey: from the Popperian and Kuhnian theses where science is taken or assumed to be the paradigm of rationality to the Maxwellian thesis of jettisoning the widely prevalent conception of science in favour of an inquiry which gives greater intellectual priority to problems of living rather than the subordinate or 'special case' problems of knowledge and understanding. It is my opinion that the thesis of Maxwell, at the very fundamental level, has some parallels with the Islamic conception of science. The crucial differences that subsequently emerge, however, outweigh the initial similarities as Islamic science is practised within a different world-view underpinned by different assumptions. It is to this world-view and fundamental assumptions that we now turn. (Further analysis of work in the sociology of science is carried out in Chapter 2).

### 1.5 A critique of modern science

Science as practised today is the product of an intellectual rebellion against the authoritarianism of institutionalized Christianity. The schism between Church and State, public life and private life, led progressively to the secularisation of science away from its practice within an ethical and moral framework to its apotheosis as a virtually value-transcendent entity. This deification of the scientific enterprise has led to two opposite and powerful intellectual reactions. On one side of the deification of science spectrum writers such as B. M. Oliver have said that 'it is time that science, having destroyed the religious basis of morality, accepted the obligations to provide a new rational basis for human behaviour - a code of ethics concerned with man's needs on earth, not his rewards in heaven' (Oliver, 1972). In an intellectually rigorous counteracting endeavour to this type of ideological fundamentalism, Paul Feyerabend has said that what we need to do is to 'free society from the strangling hold of an ideologically petrified science just as our ancestors freed us from the strangling hold of the One True Religion!' (Feyerabend, 1975).

Such an atheistic perception of science comes also from writers who hold wholly different conceptions of the scientific enterprise as compared to Oliver and Feyerabend. For example, in an attack upon the established base of monotheistic faiths, Maxwell writes:

“... the idea that ‘God’ can be a supreme person, all powerful, all knowing and all loving, is rejected as a logical, moral and religious obscenity. Such a God would be knowingly responsible for all human suffering and death engendered by natural causes, and a participant in all suffering and death caused by people (since this invariably requires collaboration from Nature). Such a God would be torturer and murderer of all mankind - infinitely more criminal than a mere Hitler or Stalin. All traditional attempts to excuse God’s torturing and killing of people are similar to, and are on the same intellectual and moral level as, attempts to excuse the torturing and killing perpetrated by a Hitler or Stalin. To call such a cosmic tyrant a being of love is the most blatant inconsistency imaginable (unless one has monstrously perverted ideas about love). To advocate publicly that an all-powerful, knowing and loving God exists, as if this is a consistent possibility (let alone a known certainty), is, from the standpoint of the philosophy of wisdom, profoundly damaging in that it strengthens the impression that reason does not apply where it most needs to be applied: to the problem of what is of supreme value to us in existence. Where it is most important for us to be rational we become carelessly and destructively irrational.” (Maxwell, 1984, pp.76-77)

Maxwell’s position, of course, is anathema to the whole enterprise of Islamic science or science in the context of Islam which, as I shall attempt to show now, views some of the assumptions of occidental science, enshrined in the Mertonian norms, as being detrimental to the interests of Muslims in particular and humanity in general. The assumptions of western science include the following factors (Merton, 1973).

Communalism: Science is public knowledge, freely available to all. That is to say, the results of research do not belong to individual scientists, but to the world at large. Scientific discoveries should be communicated immediately to the scientific community by publication in the open literature, which anyone may draw upon for their own further use.

Universalism: There are no privileged sources of scientific knowledge. In other words, discovery claims and theoretical arguments should be given weight according to their intrinsic merits, regardless of the nationality, race, religion, class, age or scientific standing of the person who produces them.

Disinterestedness: Science is done for its own sake. That is, scientists should undertake their research, and present their results with no other motive than the advancement of knowledge. They should have no personal stake in the acceptance or rejection of any particular scientific idea.

This norm, in effect, forbids any open manifestation of the psychological commitment that scientists usually feel towards their own discoveries. It emphasizes the self-effacing and dehumanizing stance that scientists are expected to adopt when making discovery claims.

Originality: Science is the discovery of the unknown. That is to say, scientific research results should always be novel. An investigation that adds nothing new to what is already well known and understood makes no contribution to science. This norm lays emphasis on the discovery element in scientific epistemology. It enjoins upon scientists diverse forms of creative behaviour and imaginative thought. Originality is an obligatory condition for the publication of a research paper, the acceptance of a PhD thesis, the award of a prize or almost any other act which merits scientific recognition. Conversely, this norm strongly censures all form of scientific plagiarism.

Scepticism: Scientists take nothing on trust. That is to say, scientific knowledge, whether new or old, should be continually scrutinised for possible errors of fact, or inconsistencies of argument. Any justifiable critical comment should at once be made public. This norm institutionalises a

context of validation within the scientific community, enforcing strict intellectual discipline and high critical standards on all scientists.

In a post-Kuhnian world it is untenable to talk of scientific disinterestedness. All other norms and assumptions underpinning the practice of occidental science-communalism, universalism, originality and scepticism - are perhaps honoured as much in the breach as in the observance. Concerning perhaps the most important norm, universalism, there is an increasing awareness that this norm is not really consistent with the social differentiation of the scientific community into distinct specialities and strata of authority. This problem is compounded by the tendency for groups of specialists to discriminate against the opinions of outsiders and laypersons as well as giving too much scientific weight to the views of members of the scientific elite.

Further criticisms of occidental science are provided by Hilary and Steven Rose who give graphic examples of political dogma masquerading as scientific truth: soviet genetics under Lysenko and Jungian psychoanalysis under the Nazis (extreme examples, admittedly). They claim that both the selection of areas for research as well as scientific concepts are politically and ideologically influenced in various degrees. (In Chapter 2, I offer a wider critique of modern science, predominantly in the context of the sociology of science.)

Ravetz, in his essay on 'Science and value' (Ravetz, 1984), points out that scientists have had the experience, in Oppenheimer's words, of 'tasting sin and are doubtlessly finding it sweet'. For Ravetz, the basic assumptions of science - which he equates with the assumptions of the Enlightenment - are intellectually frightening. That reason is supreme, nature is there to be dominated, and the purpose of science is to solve all problems are the embodiments of the

‘post-Christian’ Western actions and intellectual traditions that developed in seventeenth, eighteenth and nineteenth-century Europe and were stimulated by the rabid anticlericalism that arose after the French revolution. Having argued that the widely held view is that of the ethic of scientific truth as an uncompromisable and absolute value, Ravetz says in a startling sentence ‘yet, by some alchemy of logic, this value-free truth becomes the foundation of human values’ (Ravetz, 1984).

It thus becomes apparent that science and technology cannot be dissociated from their application, use and abuse; neither can they be divorced from the complex web of social forces that have generated them in the first place. They thus have to be shaped by more enlightened values: a robust epistemology capable of synthesizing science and technology within an ethical framework of enlightened, universally applicable values. Helga Nowotny spells out the challenge:

“The institutional system of Islamic science has become ossified and finally ceased to exist at all. The challenge it faces now is how to build new institutions of science which are at the same time concordant with its traditional concept of knowledge and can face the challenge coming from the outside.” (Nowotny, 1984, p.103)

(A more comprehensive critique of modern science is carried out in Chapter 2.)

## 2. THE ISLAMIC PERCEPTION OF SCIENCE

### 2.1 ISLAM: a world-view and a civilization

Islam is a universal system that has a specific world-view within the matrix of which all intellectual products are conceived and developed. The enterprise of science is one such product (albeit in many ways a very successful one) and should, therefore, be practised, discussed and debated within the moral and ethical circumference provided by the belief system of Islam.

A world-view is an intellectual perception of a civilization. It guides the people who hold it, consciously or subconsciously, towards establishing social, economic, political, religious and cultural structures and institutions which further propagate the world-view held by its adherents. James Steve Counelis, in his essay Knowledge, values and world-views: a framework for synthesis (Counelis, 1984), says that holistically understood, all world-views contain four structural elements: cosmology, ethos, dynamics and telos (Fig. 1.2). Cosmology he takes to mean the objective observations people make about their world and the pattern of meanings they impose upon them. Ethos are the values, evaluative methods and axiological structures attached to things and assigned to human behaviours. Dynamics constitutes the principles of internal motion that 'make' the world-view function as a psychic, social, physical and biological reality. Finally telos comprises the ordained purposes, goals and the ultimate. Counelis then proceeds to synthesize these four components into a holistic definition:

“A world-view is defined as a function of the intersect between cosmology and ethos held and practised by persons within the bounds of a particular time and place with the intersect directed towards particular goals or telos.” (Counelis, 1984, p.229)

The world-view of Islam is unreservedly and uncompromisingly holistic. It synthesizes within its purview all its components, unifying ends and means; objective observations and patterns of meanings; psychic, social, physical and biological reality; values, evaluative methods and axiological structures. With this theme of unification underpinning its eternal world-view, it sets out to practise, as we shall see later, its science and technology as an integral part of its holistically structured civilization.

Ziauddin Sardar, in his very readable essays on Islamic Futures (Sardar, 1985), describes Muslim civilization as a flower shaped model where seven areas which need contemporary intellectualization are identified (Fig. 1.3). The central core represents the world-view of Islam,



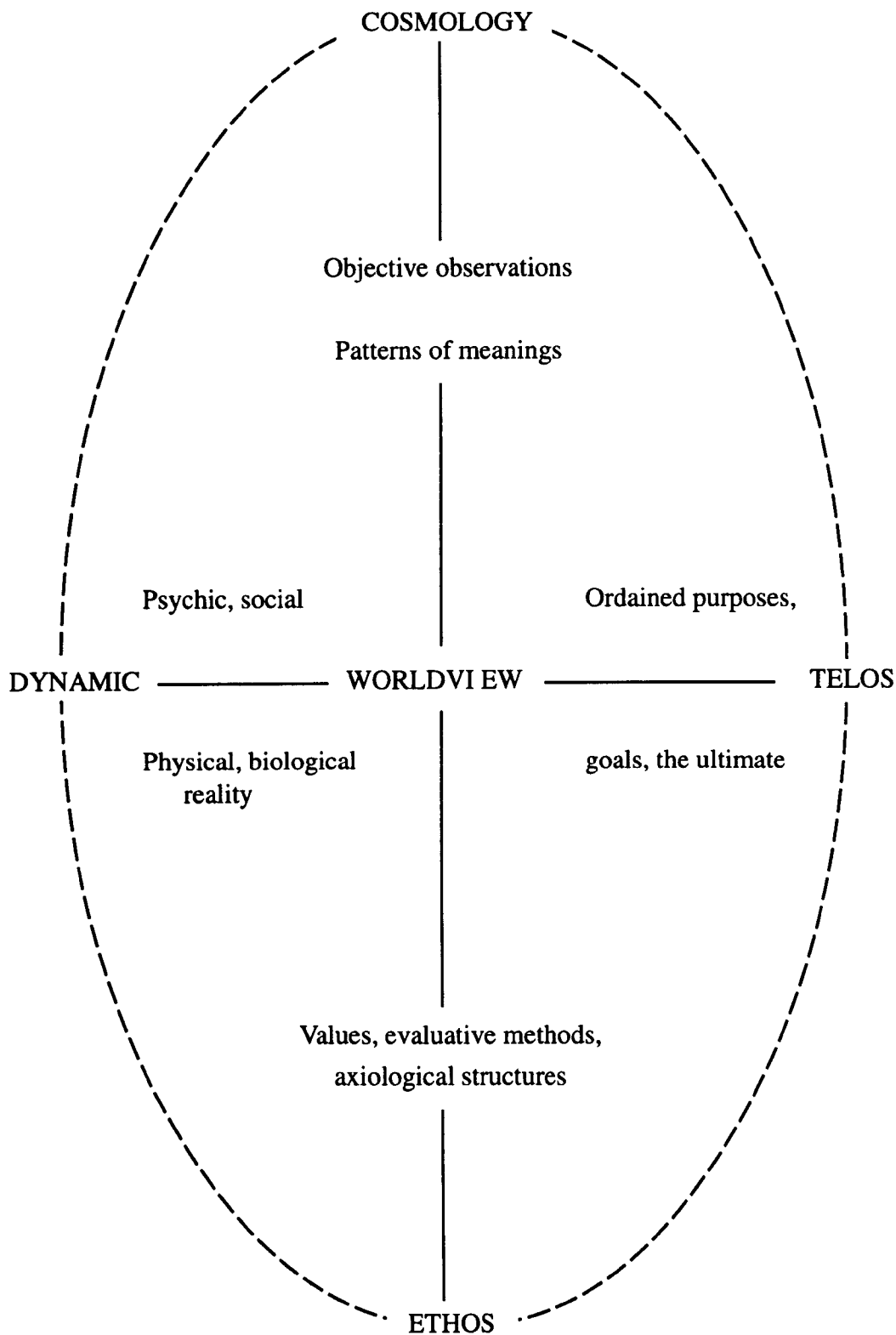


Figure 1.2 A representation of Counelis' conception of the components of a world-view (Counelis, 1984, p.231)

surrounded by two concentric circles representing the cosmology, dynamic, ethos and telos of the Islamic world-view. It is epistemology and Shariah, or Islamic law, which encapsulates the aura generated by the components of a world-view. The four petals representing the external manifestation of the world-view are arbitrary as environment could quite easily be subsumed within science and technology and economic enterprise within political and social structures. Rather than assuming the position of autonomous components they are problems and enterprises directly addressed by science and technology and political and social structures respectively. The model does, nevertheless, provide some perspective to the challenges before contemporary Muslims as they go about trying to reconstruct and rehabilitate a once dynamic and thriving civilization. Secondary external expressions of the world-view would be represented by areas such as architecture, art, education, social behaviour, community development and so on.

The representation of the model could perhaps be improved in the way shown in Figure

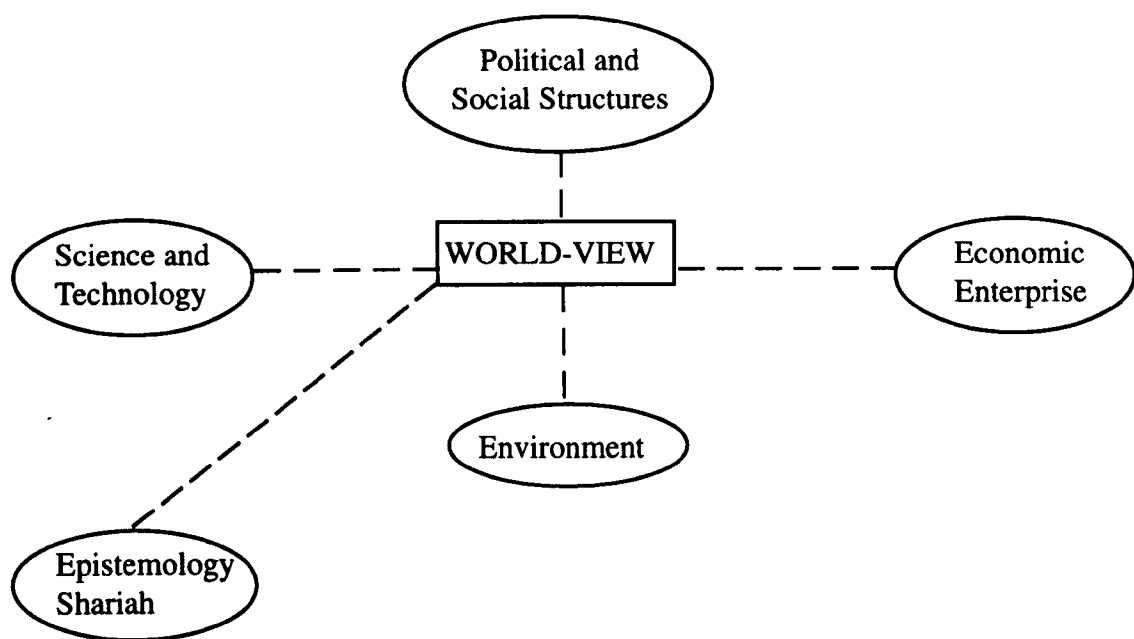


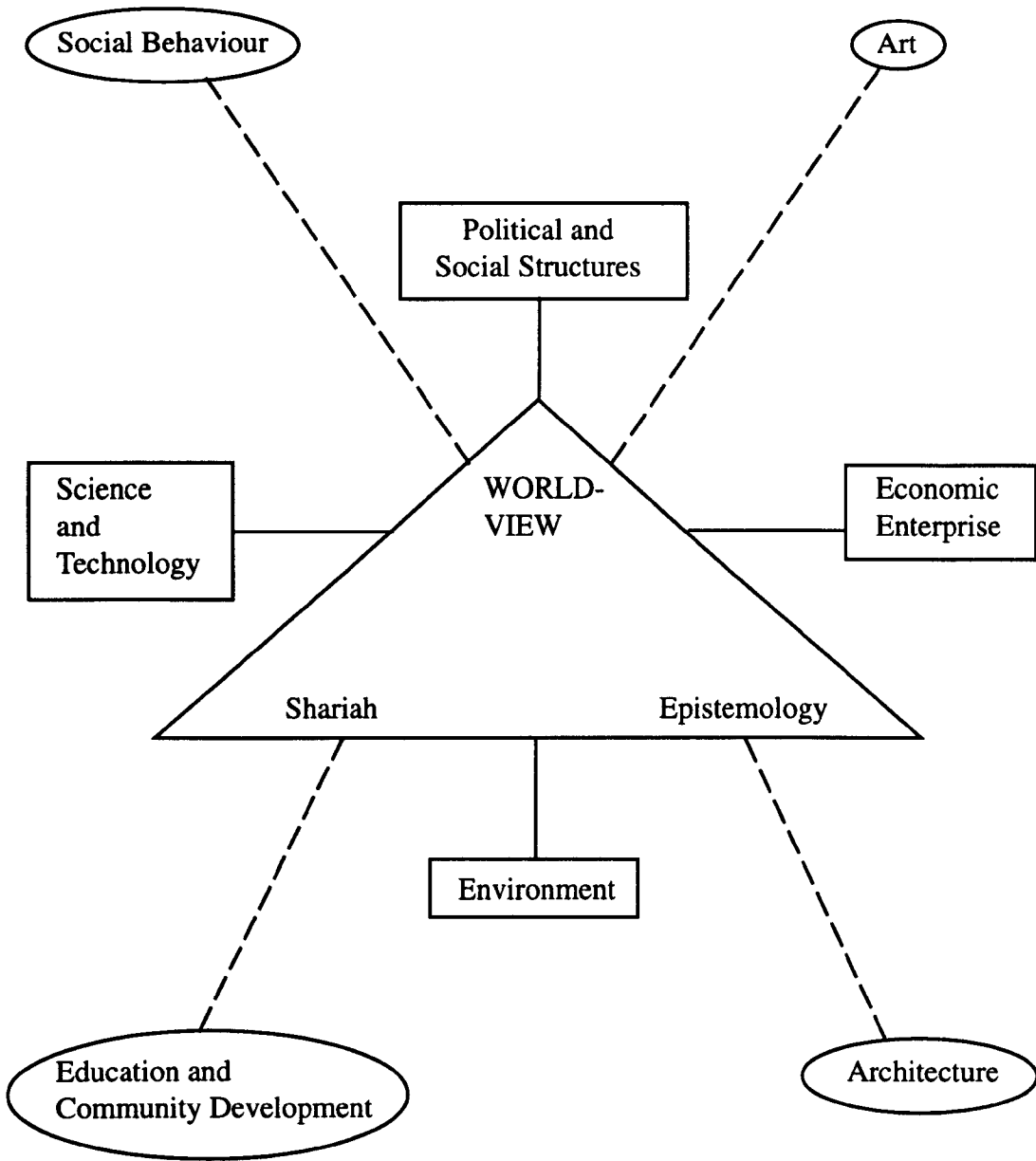
Figure 1.3      Sardar’s model of the primary components of a civilization  
(Sardar, 1985, p.68)

1.4. Here, in my judgement, the representation is of a central core world-view enshrined by Islamic epistemology and the Shariah, and surrounded by primary and secondary satellites representing intellectual and social enterprises with which it is in constant and dynamic contact. The components of the model, in the form of primary and secondary intellectual satellites, provide the theoretical foundation upon which the institutional edifice of a Muslim civilization is to be built. In essence, the world-view of Islam consists of a few principles of faith and a matrix of concepts to be found in the Quran and the Sunnah. The principles are an adumbration of the general rules of behaviour and development, chalking out the parameters within which all Islamic bodies, from individual personality to dynamic civilization, are to grow and thrive. The conceptual matrix performs a calibration function, a standard of measure for the Islamisation of particular developments and institutions, as well as serving as a basis for the theoretical and practical elaboration of the world-view of Islam.

Ziauddin Sardar, having made the valid point that the Quran and the Shariah contains numerous concepts that have been dormant for centuries, proceeds to extract over a hundred key concepts that need the urgent attention of Muslim scholars. Such scholarly attention, however, is not provided by Sardar who simply says that “they are our basic tools for the elaboration of the world-view of Islam and hence reconstruction of a dynamic, thriving Muslim civilization of the future” (Sardar, 1985). He does, however, give us important conceptual pointers in the right intellectual direction.

## 2.2 Science from the Islamic Perspective

The philosophy of science is a nascent and emerging discipline within the Islamic world. It needs to be given concrete academic foundations and a definite intellectual direction. The fundamental principles underlying the practice of Islamic science, which shall be outlined below,





Primary Satellites   
Secondary Satellites 

Figure 1.4 The dynamism of civilizational components (adapted from Sardar, 1985, p.68)

are quite clear. It is the task of unifying these principles into a cohesive, intellectually watertight network towards a robust philosophy of science that eludes Muslim scholars and thinkers.

By way of example, the late Professor Qadir ascribes the success of Muslim scientists in the golden period of Islam to their ability to observe and experiment within an inductive framework (Qadir, 1988). Thus, with surprising naivety he remarks that ‘Muslim scientists flew on the wings of inductive method and achieved marvellous successes’ (Qadir, 1988). By the time Qadir’s book was published a whole host of sophisticated argumentation against the logical, theoretical and practical fallacies of naive inductivism were in wide circulation within academic and literary circles.

#### Fundamental principles of Islamic science

“If science is not the unique intellectual construct which until so recently it was portrayed, if the history of science is not the history of iterative movements towards the truth about the natural world but rather the history of various social constructions of reality mediated through science, scientists and society, then there exists the possibility of an Islamic science that will be one facet, or more likely a series of facets, of a multidimensional world of nature, all of which are imbued with the very essence of Islamic society.” (Ford, 1984, p.34)

In this visionary statement Glynn Ford alludes to the fundamental nature of science as envisaged by Islam: science is not a unique intellectual construct, the paradigm of rationality, but an intellectual product created by the mind of man, emerging from and being shaped by human society. Its knowledge, statements and techniques have been created by human beings and developed, nurtured and shared among their groups. It is thus a gregarious activity performing a distinct social function, and not just the collection of value-free data followed by the construction of theories based upon an objective analysis. As David Morley has said,

**“The pure scientist does not exist in isolation from the rest of society: he spends its money, educates its children, heals its sick and feeds its hungry, develops its consumer products - indeed, there is almost no aspect of modern life which is untouched by science and the scientist. He is also a human being and a citizen, who makes mistakes, collaborates and competes with his scientific colleagues, tries to persuade others to do what he thinks is right; who, in short, displays all the qualities and failings of the human race. Man is an ethical animal, and so is the scientist.” (Morley, 1978, p.1)**

**Islam, as lucidly manifested in the Quran and the teachings of Prophet Muhammed, insists on the pursuit of knowledge and understanding. It is openly and unashamedly a teleological system, maintaining unity of thought in the face of economy and politics, science and technology, religion and society. It is the epistemology of Islam - of which science is a part - that provides the matrix within which all the diverse elements of existence are meshed together towards a single goal and orientation: seeking pleasure, through worship, of the Creator - Allah, the one and only universal God of all humanity.**

**Thus Islam is a total holistic system, a religion, a culture, a civilization - all at once. As such, it touches every aspect of human endeavour, Islamic ethics and values effectively permeating all human activity. Consequently, Islam has a definite philosophical, methodological, metaphysical and sociological perspective on science and technology.**

**In an Islamic society the values shaping scientific and technological endeavour would have to be Islamic values. Ali Kettani describes how Islamic values and ideals affected the work of Muslim scientists of the Golden Age of Islam and identifies five main characteristics of this period: universalism, tolerance, international character of the market, respect for science and scientists and the Islamic nature of both the ends and means of science (Kettani, 1984). He**

argues that the revival of Islamic science can only be brought about by these very values. The institutional embodiment of these values is provided by the organization of Islamic Conference (OIC) on an international level and the Islamic Foundation for Science and Technology for Development (IFSTAD) on a more nationalistic basis.

Kettani's paper shows that within an Islamic society there is no distinction between the ends and means of science. This feature, he argues, provides an effective insurance policy against the abuse and perversion of science. Such a dichotomy between ends and means exists in the practice of occidental science and in those Muslim societies which have taken occidental science as their intellectual paradigm.

In Islam there is no artificial separation or compartmentalization of science and values. Issues of science and values have to be treated within a framework of concepts that shape the goals of a Muslim society. As Sardar has said,

“These concepts generate the basic values of an Islamic culture and form a parameter within which an ideal Islamic society develops and progresses. The Stockholm seminar on ‘knowledge and values’ identified ten such concepts: tawheed (unity), khilafah (trusteeship), ibadah (worship), ilm (knowledge), halal (praiseworthy) and haram (blameworthy), adl (social justice) and zulm (tyranny), istislah (public interest) and dhiya (waste). When translated into values, this system of concepts embraces the nature of scientific inquiry in its totality: it integrates facts and values and institutionalises a system of knowing that is based upon accountability and social responsibility.” (Sardar, 1985, p.175)

How do these concepts generate the basic values of an Islamic culture which shape scientific and technological activity? An attempt will be made to explain this. Before doing so, however, it is advisable to note that the universal language of Islam, namely Arabic, in an etymological context follows the same holistic pattern as the parent system. Thus, many words and concepts, such as those which follow, cannot be adequately translated into the English language without losing some of the comprehensive and holistic flavour of the original.

The concept of tawheed, usually translated as unity of God, is the quintessential metaphysical principle as well as a teleological axiom: the universe is created by God who is its final end. Tawheed dictates the acceptance of God as the only source of all values. It thus inculcates a psychological and behavioural attitude, a unitary attitude that pervades Muslim philosophy, epistemology and technology. It integrates nature and ethics, asserting unity of man and nature, purpose and goal, means and ends, knowledge and values.

From tawheed emerges the concept of khilafah: that man is a vice-regent of God, wholly dependent upon Him, and responsible and accountable to Him for all his multifarious activities, including science and technology. Man has accepted nature as a trust and is thus a custodian of nature. Rejected is one of the popular occidental conceptions of science based upon Francis Bacon's aphorism that 'nature reveals its secrets under torture', together with the Biblical equivalent of encouraging dominion over nature.

The essence of Ibadah is the contemplation of the unity of God, the quintessential form of worship. It leads to an awareness of tawheed and khilafah, serving as the matrix within which science and Islamic values are integrated and synthesized. Because Ibadah is the contemplation of the unity of God, it has a number of manifestations of which the pursuit of knowledge is the prime one.

When pursued within an Islamic framework, the concept of knowledge - ilm - is transmogrified into a value. Epistemological taxonomy was a major achievement of many Muslim classical writers from al-kindī (d.873), al-Farabī (d.950) and al-Bīrūnī (d.1048) to ibn Khaldūn (d.1406). One of the finest articulations of Islamic epistemology, still relevant today, is that of the celebrated Muslim scholar Al-Ghazzālī (1058-1111), a professor at the Nizamiyya Academy at Baghdad. Al-Ghazzālī analysed knowledge on the basis of three criteria:



### 1. The Source

- (a) Revealed knowledge: 'it is acquired from the Prophets and is not arrived at either by reason, like arithmetic, or by experimentation, like medicine, or by hearing, like languages'.
- (b) Non-revealed knowledge: primary sources of this type of knowledge are reason, observation, experimentation and acculturation.

### 2. The level of obligatoriness

- (a) Individually requisite knowledge (Fard-ayan): that is knowledge which is essential for an individual to survive, e.g. ethics, morality and law.
- (b) Socially requisite knowledge (Fard Kifaya): that which is for the survival of the whole community, e.g. agriculture, medicine, architecture, engineering.

### 3. The social function

- (a) Praiseworthy sciences: these are useful and indispensable sciences 'on whose knowledge the activities of this life depend...'
- (b) Blameworthy sciences: these would include astrology, magic and, in the modern world, certain types of war sciences, genetic engineering, socio-biology, techniques of torture, etc.

(The criteria of blame and praise were discussed with science teachers working in Muslim schools. Praiseworthy science was loosely defined as that pursued with the teleological aim of glorifying the Creator, while blameworthy science is that pursued by those not acknowledging His existence. This definition is, of course, highly problematic. My findings are discussed extensively in Chapter 8.)

The pursuit of non-revealed knowledge is an obligation under the dictates of ibadah, while revealed knowledge provides the ethical and moral framework within which knowledge is pursued. The pursuit of knowledge must have direct and pertinent social relevance. There is no place in the epistemology of Islam for the commonly held occidental notions of science for science's sake and science as a means to an end.

Islamic science is non-utilitarian but very much responsive to social needs and priorities. Halal and haram are the conceptual forces which operate to maintain this delicate balance. In its most comprehensive sense, haram includes all that is destructive for man - in the physical, mental and spiritual sense. Thus any force or effect arising from the multifarious activities of man, which militates against the delicate balance between man and nature, would fall into the category of haram, i.e. it would not be a permissible act. On the other hand, all the constructive forces and factors that are beneficial for an individual, his society and his environment are halal. What happens, however, when an action that brings benefits to an individual has harmful effects on society or the environment or both? Precisely to counteract such an eventuality, halal operates on the premises of the distribution of adl (social justice). The propagation of haram activities, however, results in the propagation of zulm (tyranny). Zulm can be perpetrated between man and God, between man and man and between man and nature. Thus scientific and technological activity that seeks to promote adl in all its societal manifestations (social, political, economic, institutional) is halal, while that science and technology which results in destruction of the natural environment, dehumanisation and alienation, is zalim (tyrannical) and therefore haram.

The third pair of concepts that shape the direction of Islamic science are dhiya (wasteful) and istislah (public interest). Zalim (tyrannical) science and technology generate waste as a result of the destruction of human, environmental and spiritual resources. Such science is therefore categorized as dhiya (wasteful). The conceptual legitimacy of scientific and technological activity

that promotes adl is derived from istislah or public interest, which is the chief supplementary source of Islamic law.

These key Islamic concepts provide a simple contemporary model of Islamic science (Figure 1.5), but one which has yet to be fleshed out and given a concrete intellectual foundation. The three central concepts of tawheed, khilafah and ibadah shape the paradigm of Islamic science. Concepts such as akhirah (the hereafter), taqwa (God-consciousness), hikma (wisdom) and ijma (consensus), may also be very fruitful in the process of the contemporisation of Islamic science. There is no conceptual limit as such: interweaving and cross-fertilisation between the stated concepts would result in the elaboration of contemporary models of Islamic science.

Within this paradigm - which is absolute - Islamic science operates through the agency of ilm to promote adl and istislah and undermine zulm and dhiya. Social justice and public interest are not really possible without putting into practice the concept of taqwa (God-consciousness) which helps to harmonise the means and ends in the production of knowledge. Thus a Muslim scientist is accountable both socially and spiritually which means that he must emphasise the social relevance in both his pursuit and application of knowledge.

It is my view that due to the relativistic connotation of a Kuhnian paradigm, it is inappropriate to apply the term to Muslim concepts that are deemed to be absolute. I would favour an expression such as absolute metaphysical construct, which focuses not only on the eternal nature of Islamic concepts but also on their transcendence over derived scientific laws and processes.

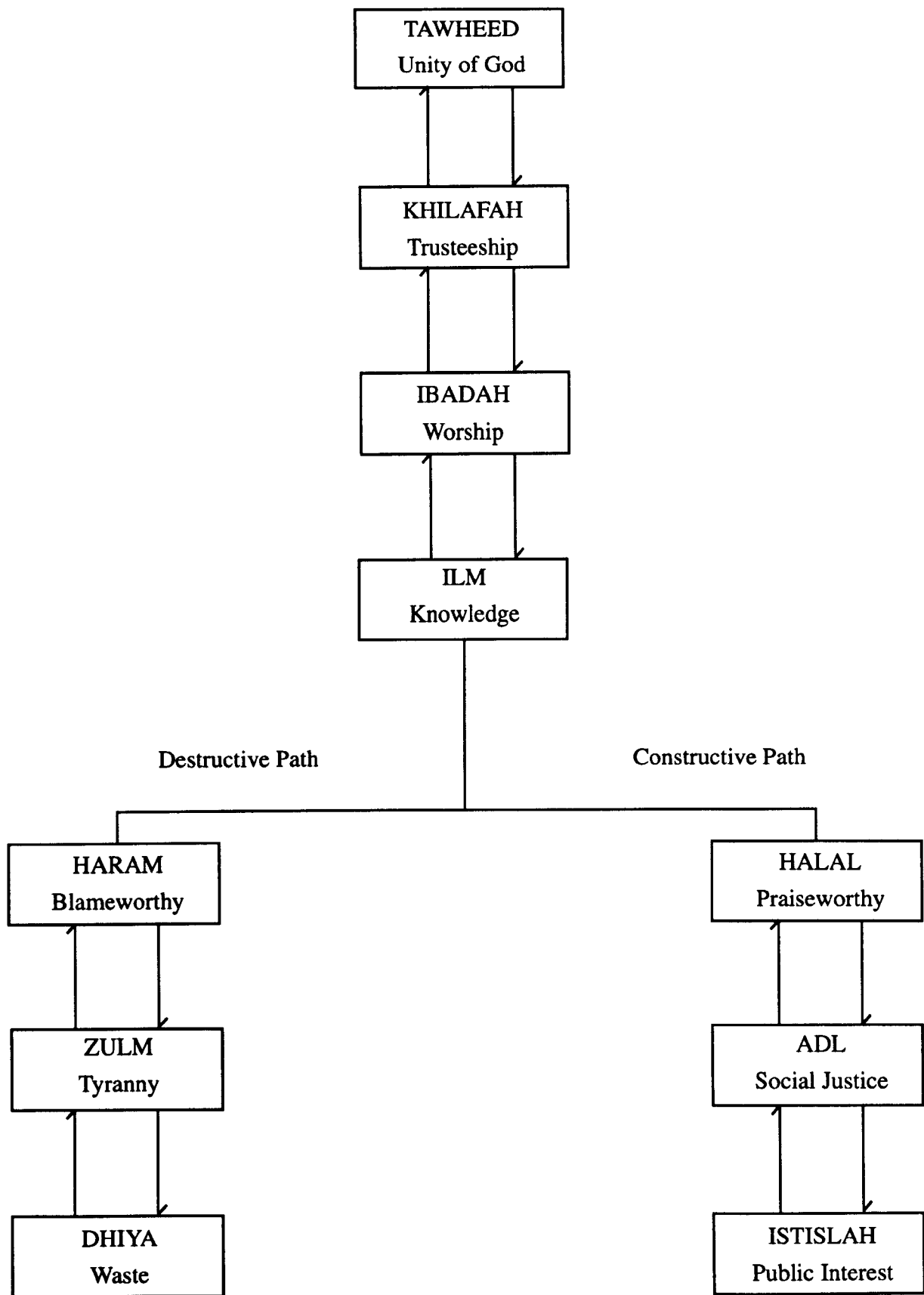


Figure 1.5 A simple contemporary model of the paradigmatic concepts underlying the practice of Islamic science (my own construction)

### 2.3 Islamic Science: the contemporary debate

Popperian and Kuhnian versions of science, together with the views of other modern critics of the scientific enterprise, are now just beginning to have an impact on Muslim scientists and scholars. Unfortunately, at the moment, the belief in the objectivity, value-neutrality and unquestioned rationality of science still holds sway in many Muslim intellectual circles. A number of conferences over the last decades however, together with the institutionalisation of Islamic science as a discipline with its own journals, is progressively fostering the awareness of the social foundations of scientific knowledge.

Ziauddin Sardar has found that the interest in discovering a contemporary style of doing science which fully incorporates the ethical dictates of Islam and is an embodiment of Islamic culture and tradition is particularly strong among the young scientists and intellectuals. Sardar visited university campuses throughout the Muslim world for the British science journal *Nature* and discovered some striking generational differences as a result of his study. He found that the older Muslim scientists tended to cling to the international view of the value-neutrality and objectivity of science. The younger scientists, however, were calling for a science based on the world-view of Islam, circumscribed by its unique ethical and moral framework (Sardar, 1985).

The attitudinal difference between the young and the more senior Muslim scientists have produced distinctly different approaches to the issue of science and Islam. In the first category there are, whom I call, the universal rationalists who believe in the value-neutrality, universality and international culture of science. According to them, science is the paradigm of rationality that provides a universal criterion for theory choice and is not culture specific, having the same potential benefit for all cultures.

A second category of Muslim scientist - the Quranologists (once again my label) - legitimise, perhaps inadvertently, the misconceived perception of the universality of modern science by equating it with the verses of the Quran. The major component of their intellectual armoury is their emphasis on the fact that the Quran contains some 750 verses stressing the pursuit of knowledge, use of the intellect (reason) and integrating science in the life of the community (Bucaille, 1981). Furthermore, it is pointed out that the Quran mentions several scientific facts and theories which have been accorded validation by recent research and discoveries. All this leads to a dangerous conclusion: because the facts and theories revealed in the Quran 1400 years ago have been accorded western scientific validity the divine authenticity of the Quran is confirmed. The corollary of this highly misconceived thinking is that if established scientific facts and theories find their confirmation in the Quran then the enterprise which generates them - science - must perforce have the same universal validity as the Quran.

Quranology is a philosophy of science whose moral and intellectual equivalent is modern day scientology. The arch proponent of this type of approach to science and Islam is the French physician Maurice Bucaille. In his very popular book, The Bible, The Quran and Science which enjoys a remarkable following in Muslim intellectual and academic circles, Bucaille writes in conclusion that

“The Quran most definitely did not contain a single proposition at variance with the most firmly established modern knowledge, nor did it contain any of the ideas current at the time of the subjects it describes. Furthermore, however, a large number of facts are mentioned in the Quran which were not discovered until modern times. So many, in fact, that on November 9, 1976, the present author was able to read before the French Academy of Medicine a paper on the ‘Physiological and Embryological data in the Quran’. The data -like many others on differing subjects - constituted a veritable challenge to human explanation - in view of what we know about the history of the various sciences through the ages. Modern man’s findings concerning the absence of scientific error are therefore in complete agreement with the ‘Muslim exegetes’ conception of the Quran as a Book of Revelation. It is a consideration which implies that God could not express an erroneous idea.” (Bucaille, 1981, p.7)

It is just that consideration expressed in the last sentence which could imply the very opposite. Because, by equating the Quran with science, the latter acquires its intellectual apotheosis since divine revelation now becomes subject to the verification of occidental science - a very dangerous development for Muslim civilization.

In contrast to Quranology, a third category of Muslim scientist take a more critical attitude towards the scientific enterprise. They make a distinction between the nature of science and its function and applications. Thus, the myth of paradigmatic rationality, objectivity and neutrality still persists in the domain of explaining the nature of science. In the realm of application, however, the proponents of this approach, whom I shall refer to as the Islamic functionalists, argue that when science is pursued within an Islamic polity its functions are modified to serve Islamic ideals and Muslim societies. Putting into practice the dynamic component of Islamic law - ijtihad - ensures that science is used for the cultural and intellectual benefit of Muslim communities. Sardar claims that the cause of 'science in Islamic polity', or 'Islamic functionalism' as I have described it, has been particularly championed by Pakistani scientists. In his book, Islamic Futures, he refers to a paper presented to the International Conference on Science in Islamic Polity by Z A Hashmi of the Pakistan Academy of Sciences in order to substantiate his claim. The quotation is lengthy but well worth reproducing:

"A culture with such an exalted vision of man's role and responsibilities and with such a commitment to seek understanding, knowledge and truth through observation, reflection and reasoning (as Islam) provides the ideal motivation and environment for the cultivation of science. There is thus no reason at all to blindly follow the West (which faced a totally different situation) and divorce religion from the scientific and developmental activities in Muslim polity, for Islam does not constitute an impediment but is a source of strength for science...

"The renaissance of science in the Muslim ummah must thus be accomplished within the parameters of Islamic consciousness. There is a great challenge to reclaim and rehabilitate the elements of vitality and beauty from the treasure-house of our cultural tradition. Without this, the transfer of Western science and technology would have highly disruptive consequences on the nature of our

society and culture. While accepting modern science and technology, the Muslim ummah must arrange to carefully screen such transfer and eliminate the mechanistic, hedonistic and deterministic tendencies and the amoral stance of the West, which is accompanying the thoughtless and mechanical transfer of science and technology from Western societies.” (Hashmi, 1983, p.4)

Thus the Islamic functionalist message is that the international Muslim community - the ummah - should accept the content and structure of Western science and technology but simultaneously running an intellectual screening process to eliminate the ‘mechanistic, hedonistic and deterministic tendencies of the West’. The fundamental point that this approach and those who espouse it fail to grasp, however, is the formidable power of western science to change a polity beyond recognition. The entire system of science that exists today is so deeply entrenched in Western values and culture; so much so that even experimental and quantitative techniques are influenced by this metaphysical framework. Consequently, the wholesale importation of Western science and technology in Muslim societies promotes nothing but persistent tension and conflict between the goals of this science and Islamic polity. (These issues are further discussed in Chapter 2.)

Leading us into the fourth and most recent ‘approach to the relationship between science and Islam’, Sardar writes:

“It has been argued by certain scholars that a science whose processes and methodologies incorporate the spirit of Islamic values, promote such ideals and goals of the world-view of Islam as brotherhood, social justice, adequate use of natural resources, remind man of his trusteeship of God and increase spiritual awareness, and serve the needs and requirements of Muslim societies, is quite a different entity in nature and style than modern science. As it is an embodiment of the value, culture and the intellectual tradition of Islam, it is most appropriately called Islamic science.” (Sardar, 1985, p.176)

Such a view is espoused by the Ijmalis, a name they have accorded themselves meaning synthesis within the framework of aesthetics. As was first pointed out by Seyyed Hossein Nasr, there is an Islamic alternative to Western science. Nasr eloquently argued that the role and applications of Western science have lost their legitimacy (even though science is legitimate in



itself) as a result of its dismemberment from a higher form of transcendental and revelatory knowledge (Nasr, 1968).

So the search is on for evidence from the history of Islamic science to suggest that it had a distinct identity which differed radically from the nature and style of western science as it is practised today. The major flawed assumption from the linear occidental perspective has been that Muslim civilization was like a temporary historical custodian which preserved Greek intellectual heritage and passed it on to its rightful owner, the European civilization. This 'piggy in the middle' type of approach to the history of science is now gradually giving way to a more enlightened historical analysis though, admittedly, the intellectual process has only just begun.

The first steps towards meeting this challenge have been to examine modern science within the framework of moral and ethical concepts that underpin the course of Muslim society. These have been described in the previous section on science from the Islamic perspective.

Sardar spells out the position very clearly, although I disagree with his absolutist perception concerning the western methodology of science. (I return to my criticism of Sardar's conception towards the end of this chapter.)

"This unique nature and characteristic style means that while Islamic science values systematic, vigorous search for truth, it is not 'objective' in a clinical sense - it does not kill off all it touches. Concerns for social welfare and public interest, promotion of beauty and a healthy, natural environment as well as systematic observation and experimentation and rigorous mathematical analysis are hallmarks of Islamic science in history. As such Islamic science is subjectively objective: that is, it seeks subjective goals within an objective framework. The subjective, normative goals include seeking the pleasure of Allah, the interests of the community, promotion of such eternal Islamic values adl (justice) ibadah (worship) and khilafah (man's trusteeship). This contrasts sharply with naive inquiry which is based on emotions, dogma, bias and prejudices. Islamic science

has nothing to do with magic and occult: it does not seek to introduce anarchy and dogmatism into the pursuit of knowledge, neither does it seek to impose the method of one discipline on to another. It simply seeks to give equality to all methods of inquiry, and promote research and development within a framework of ethics and values which by nature are subjective. It therefore also contrasts radically with Western science which excludes all other branches of knowledge and is based on a single method which is considered to be outside human values and societal concerns. Islamic science, on the other hand, seeks a total understanding of reality. It is thus a very holistic enterprise.” (Sardar, 1985, p.33)

### 3. WESTERN SCIENCE AND ISLAMIC SCIENCE JUXTAPOSED

#### 3.1 Comparing intellectual traditions

Feyerabend, in Against Method, has said that it is not possible, at the moment at any rate, to make a judgmental comparison between two intellectual traditions using criteria which transcend both (Feyerabend, 1975). If criteria are used from the first tradition to analyse the second then, inevitably, the first tradition is the victor. If, however, criteria are used from the second tradition to analyse the first then, inevitably again, the second tradition would come out on top. At present, a super-paradigm does not exist by which other paradigms (or world-views) may be compared.

In juxtaposing western science and Islamic science I will not be using an implied set of metaphysical criteria to intellectually demolish the former and bring out the superiority of the latter. Rather, I shall be making a tabulated comparison between the two intellectual traditions in order to identify the key differences between them.

Such an exercise has been attempted by Ziauddin Sardar; in my view, however, it is not wholly satisfactory. I reproduce below Sardar’s tabulated comparison between western science and Islamic science, followed by a further re-tabulation with my own additional explanatory comments and criticisms.

3.2     **A Comparison Between Western Science and Islamic Science** (after Sardar, 1984)

**Norms of Western Science**

- 1.    **Faith in rationality.**
- 2.    **Science for science’s sake.**
- 3.    **One all-powerful Method the only way of knowing Reality.**
- 4.    **Emotional neutrality as the key condition for achieving rationality.**
- 5.    **Impartiality - a scientist must concern himself only with the production of new knowledge and with the consequences of its use.**
- 6.    **Absence of bias - the validity of scientific statement depends only on the operations by which evidence for it was obtained, and not upon the person who makes it.**

**Norms of Islamic Science**

- 1.    **Faith in revelation.**
- 2.    **Science is a means for seeking the pleasure of Allah; it is a form of worship which has a spiritual and a social function.**
- 3.    **Many methods based on reason as well as revelation, objective and subjective, all equally valid.**
- 4.    **Emotional commitment is essential for a spiritually and socially uplifting scientific enterprise.**
- 5.    **Partiality towards the Truth: that is, if science is a form of worship a scientist has to concern himself as much with the consequences of his discoveries as with their production; worship is a moral act and its consequences must be morally good; to do any less is to make a scientist into an immoral agent.**
- 6.    **Presence of subjectivity; the direction of science is shaped by subjective criteria: the validity of a scientific statement depends both on the operation by which**

evidence for it was obtained and on the intent and the world-view of the person who obtained it; the acknowledgement of subjective choices in the emphasis and direction of science forces the scientist to appreciate his limitations.

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| <p>7. Suspension of judgement - scientific statements are made only on the basis of conclusive evidence.</p>   | <p>7. Exercise of judgement - scientific statements are always made in the face of inconclusive evidence; to be a scientist is to make expert, as well as moral judgement, on the face of inconclusive evidence; by the time conclusive evidence has been gathered it may be too late to do anything about the destructive consequences of one's activities.</p> |
| <p>8. Reductionism - the dominant way of achieving scientific progress.</p>  | <p>8. Synthesis - the dominant way of achieving scientific progress; including the synthesis of science and values.</p>  |
| <p>9. Fragmentation - science is too complex an activity and therefore has to be divided into disciplines, sub-disciplines and sub-subdisciplines.</p> | <p>9. Holistic - science is too complex an activity to be divorced and isolated into smaller and smaller segments; it is a multi-disciplinary, interdisciplinary and holistic enterprise.</p>  |
| <p>10. Universalism - although science is universal, its primary fruits are for those</p>  | <p>10. Universalism - the fruits of science are for the whole of humanity and knowledge</p>  |

who can afford to pay, hence secrecy is justified.

and wisdom cannot be bartered or sold; secrecy is immoral.

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| 11. Individualism - which ensures that the scientist keeps his distance from social, political and ideological concerns.            | 11. Community orientation; the pursuit of science is a social obligation (fard kifaya); both the scientist and the community have rights and obligations on each other which ensure interdependence of both.  |
| 12. Neutrality - science is neutral, it is neither good nor bad.  | 12. Value orientation - science, like all human activity is value laden; it can be good or evil, "blameworthy" or "praiseworthy", science of germ warfare is not neutral, it is Evil.   |
| 13. Group loyalty - production of new knowledge by research is the most important of all activities and is to be supported as such. | 13. Loyalty to God and His Creations - the production of new knowledge is a way of understanding the "signs" of God and should lead to improving the lot of His creation - man, wildlife and environment. It is God Who has provided legitimacy for this endeavour and therefore it must be supported as a general activity and not as an elitist enterprise. |
| 14. Absolute freedom - all restraint or control of scientific investigation is to be resisted.                                      | 14. Management of Science: science is an invaluable resource and cannot be allowed to be wasted and go towards an   |

evil direction; it must be carefully managed and planned for and it should be subjected to ethical and moral constraints.

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| <p>15. Ends justify the means - because scientific investigations are inherently virtuous and important for the well-being of mankind, any and all means - including the use of live animals, human beings and foetuses - are justified in the quest for knowledge.</p> <p>(Sardar, 1984)</p> | <p>15. Ends do not justify the means - there is no distinction between the ends and means of science, both must be <u>halal</u> (permitted), that is, within the boundaries of ethics and morality.</p> |
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Sardar has identified key themes in the context of which, in his view, occidental science and Islamic science operate. This has profound implications for Islamic science education, for if these absolutist divisions become the basis of a nature of science course for Muslim science teachers then, in my view, inaccurate conceptions will be imparted. The impression given is that Islamic science is a clearly defined intellectual construct when, in fact, the Islamic idea of science set in a cultural framework is what we are really talking about. In my view, science in the context of Islam more accurately describes what we are trying to achieve. I offer below some comments on Sardar's 'black and white', absolutist tabulated comparison.

3.3    Retabulation of Sardar’s Comparison with Further Explanatory Commentary and Criticisms

**A comparison between Western science and Islamic Science**

Norms of Western Science		Norms of Islamic Science	Commentary
1.	Faith in rationality.	1.	Islamic science does not position revelation within the realm of theology. There is no such compartmentalisation: rationality and revelation are integral, complementary components of the world-view of Islamic science.
		1.	
2.	Science for science’s sake.	2.	In the Islamic perspective, science is one tool for the realisation of religious goals; in the western purview science itself is often depicted as an universal religion. The practice of science for science’s sake undermines the role of the Muslim as Khilafah, or trustee, of his Creator. Every human act has a transcendental implication and the practice of science is no exception.
		2.	
3.	One all-powerful Method the only way of know Reality.	3.	I do not quite agree with this distinction. If Western science does indeed have one all-powerful <u>Method of knowing Reality</u> , then it is preposterously difficult to pinpoint it. There may be a variation in the methods of analysis applied by Western scientists in the contexts of discovery and justification. However, the
		3.	

central thesis which, I believe, permeates the fabric of Western science is its implicit, but almost palpable, claim to be the paradigm of rationality. Islamic science, on the other hand, is based on the belief in revelation as the ultimate criterion of truth, rationality being complementary but subordinate to it.

I do not think that this is a valid point. In a post-Kuhnian world, emotional commitment to a paradigm is a prerequisite for maintaining scientific rationality within the scientific community. The emotional commitment of Muslim scientists is a direct consequence of science being practised as a form of worship for the pleasure of Allah, within a clearly defined ethical framework flowing directly from revelatory guidelines.

The accountability of Muslim scientists is both social and spiritual. A natural science that develops within the conceptual framework outlined earlier in this chapter, would also promote taqwa (God-consciousness), harmonise the means and ends in the production of knowledge, and emphasise social relevance in both the pursuit and application of knowledge.

Emotional commitment is essential for a spiritually and socially uplifting scientific enterprise.

Partiality towards the Truth: that is, if science is a form of worship a scientist has to concern himself as much with the consequences of his discoveries as with their production; worship is a moral act and its consequences must be morally good; to do any less is to make a scientist into an immoral agent.

Emotional neutrality as the key condition for achieving rationality.

Impartiality - a scientist must concern himself only with the production of new knowledge and with the consequences of its use.



6. Absence of bias - the validity of scientific statement depend only on the operations by which evidence for it was obtained, and not upon the person who makes it.
6. Presence of subjectivity: the direction of science is shaped by subjective criteria: the validity of a scientific statement depends on both on the operation by which evidence for it was obtained and on the intent and the world-view of the person who obtained it; the acknowledgement of subjective choices in the emphasis and direction of science forces the scientist to appreciate his limitations.
6. This, I feel, is an intellectually weak statement. Scientific statements are made within the context of a world-view, a Kuhnian 'disciplinary matrix', or, as I have referred to earlier within the context of Islamic science, an absolute metaphysical construct. If, however, the validity of scientific statements is deemed to be a function of the intent of those who make them, then the credibility of the scientific enterprise would be based on the analytical pronouncements of Psychologists and Psycho-analysts. The problems in identifying individual intent are plainly horrendous and, if used as a criterion in assessing scientific validity, would make an intellectual mockery of the whole enterprise.

7. Suspension of judgement - scientific statements are made only on the basis of conclusive evidence.
7. Exercise of judgement - scientific statements are always made in the face of inconclusive evidence; to be a scientist is to make expert, as well as moral judgement, on the face of inconclusive evidence; by the time conclusive evidence has been gathered it may be too late to do anything about the destructive consequences of one's activities.
7. Sardar is being quite indiscreet here. It is not scientific statements per se that are made in the face of inconclusive evidence; within the context of Islamic science; rather, it is pronouncements pertaining to the context of discovery - the metaphysical philosophical and theological. These pronouncements have far-reaching implications, shaping the direction in which science and technology travel, before any destructive consequences arise as a result of inaction or belated action. My view is that conclusive evidence is

required before making factual statements about the nature of the universe.

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| 8.  | Reductionism - the dominant way of achieving scientific progress.   | 8.  | Synthesis - the dominant way of achieving scientific progress; including the synthesis of science and values.   | 8.  | The synthesis of science and values, as earlier conceptualised, is the central theme underlying the practice of Islamic science.   |
| 9.  | Fragmentation - science is too complex an activity and therefore has to be divided into disciplines, sub-disciplines and sub-disciplines. | 9.  | Holistic - science is too complex in activity to be divorced and isolated into smaller and smaller segment; it is a multidisciplinary, interdisciplinary and holistic enterprise.                                 | 9.  | The civilisation of Islam, of which science and technology is a major component, is based on a holistic philosophy. Islamic science is therefore a more comprehensive and holistic enterprise than Western science which tends to be excessively preoccupied with over-specialisation and compartmentalisation, leading in turn to the intellectual/institutional isolation of sub-disciplines and their proponents. |
| 10. | Universalism - although science is universal, its primary fruits are for those who can afford to pay, hence secrecy is justified.         | 10. | Universalism - the fruits of science are for the whole of humanity and knowledge and wisdom cannot be bartered or sold; secrecy is immoral.   | 10. | The fruits of Islamic science are utilised in the service of humanity. This is a natural corollary to its holistic nature. Secrecy, although in general immoral, may be a necessary requirement in a few situations.   |
| 11. | Individualism - which ensures that the scientist keeps his distance from social, political and ideological concerns.                      | 11. | Community orientation; the pursuit of science is a social obligation ( <u>fard kifaya</u> ); both the scientist and the community have rights and obligations on each other which ensure interdependence of both. | 11. | Every Muslim scientist has the inalienable right to make pronouncements concerning the social, economic and political consequences of the research that he is engaged in. These pronouncements are made in view of the ethical and conceptual framework within which Islamic science is practiced.   |

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| <p>12. Neutrality - science is neutral, it is neither good nor bad.</p>  | <p>12. Value orientation-science, like all human activity is value laden; it can be good or evil, "blameworthy" or "praiseworthy", science of germ warfare is not neutral, it is Evil.</p>   | <p>12. An intellectual smokescreen should not be erected between the context of discovery and the context of justification in science. The practice of science should be viewed holistically, as an enterprise which is not value-free and neutral but one in which numerous types of social, economic and ideological factors play a significant - perhaps even crucial - part.</p>         |
| <p>13. Group loyalty - production of new knowledge by research is the most important of all activities and is to be supported as such.</p> | <p>13. Loyalty to God and His Creations - the production of new knowledge is a way of understanding the "signs" of God and should lead to improving the lot of His creation - man, wildlife and environment. It is God Who has provided legitimacy for this endeavour and therefore it must be supported as a general activity and not as an elitist enterprise.</p> | <p>13. The Muslim scientist does not practice science as a Popperian falsificationist or Kuhnian normal scientist. Rather, he practises his activity with explicitly stated fundamental metaphysical assumptions based upon revelation. He is primarily concerned with probing the universe for the ayat or "signs" of God, the pleasure of the Creator being his over-riding endeavour.</p> |
| <p>14. Absolute freedom - all restraint or control of scientific investigation is to be resisted.</p>                                      | <p>14. Management of Science: science is an invaluable resource and cannot be allowed to be wasted and go towards an evil direction; it must be carefully managed and planned for and it should be subjected to ethical and moral constraints.</p>   | <p>14. The conceptual matrix within which Islamic science is practiced would ensure that it is subjected to the necessary ethical and moral control so that its destructive potential does not materialise. Scrupulous management and planning in selecting areas for research is essential for directing science towards a socially and humanitarily beneficial direction.</p>              |

15. Ends justify the means - because scientific investigations are inherently virtuous and important for the well-being of mankind, any and all means - including the use of live animals, human beings and foetuses are justified in the quest for knowledge.
15. Ends do not justify the means - there is no distinction between the ends and means of science, both must be halal (permitted), that is, within the boundaries of ethics and morality.
15. Both the ends and means of Islamic science must be of an Islamic nature. This harmonises the means and ends in the production of knowledge, and emphasises social relevance in both the pursuit and application of knowledge.

The critique of Sardar's Islamic science schemata is based on developments in the philosophy and sociology of science stretching over the past four decades. The analysis of scientific practice has become a multi-dimensional enterprise with inputs from philosophy, sociology, psychology and anthropology. This, of course, has an impact ultimately on the theory and practice of science teaching in the classroom. Hence, we must now turn our attention to a critical analysis of issues arising from some of the multi-dimensional inputs mentioned above.

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## **CHAPTER 2**

### **CRITICAL ANALYSIS OF ISSUES ARISING FROM THE CONTEMPORARY SCIENCE/ SCIENCE FROM ISLAMIC PERSPECTIVE DEBATE**

- 2.1 Making Sense of Science
- 2.2 Science and Values
- 2.3 Islamic Science/Science in the Context of Islam
- 2.4 Rediscovering an Intellectual Heritage



## CRITICAL ANALYSIS OF ISSUES ARISING FROM THE CONTEMPORARY SCIENCE / SCIENCE FROM ISLAMIC PERSPECTIVE DEBATE

### 2.1 Making Sense of Science

What is science? The definition of science is becoming increasingly difficult to pin down. In Western tradition, up to quite recently, science was seen as the quest for objective knowledge of nature and reality and scientists were regarded as quasi-religious supermen, heroically battling against all odds to discover the truth. And the truths they wrestled out of nature were said to be absolute: objective, value free and universal (as discussed in Chapter 1). As a sociologist in the 1940s described it science reflects the character of nature: “The stars have no sentiments, the atoms no anxieties which have to be taken into account. Observation is objective with little effort on the part of the scientist to make it so” (quoted by Margaret Jacob, 1994). This classical view of science as ‘natural’ contrasts sharply with those of embryologist Lewis Wolpert who, while arguing that science is objective and value-free, describes it as ‘unnatural’. Science is special: it is counter-intuitive; scientific knowledge is beyond common sense, everyday experience and is unique and universal (Wolpert, 1992). J D Bernal suggested that science is all about ‘rationality, universalism’ and ‘disinterestedness’ (Bernal, 1967). Lord Rutherford settled for a more elegant definition: ‘science’, he has been widely reported to have said, is simply ‘what scientists do’.

But what do scientists actually do? The picture of truth loving and truth seeking scientists working for the benefit of humanity is rather at odds with the public conception of science and scientists. Consider, for example, what we have been reading in the serious press, recently, about what scientists have been doing:

- In Porton Down research establishment in England scientists have been using live animals to test body armour. 'The animals were strapped on to trolleys and subjected to blasts at either 600 or 750mm from the mouth of the explosively driven shock tube', wrote Tom Wilkie the science editor of the *Independent*. Initially, monkeys were used in these experiments but scientists later switched to shooting pigs. 'The animals were shot just above the eye to investigate the effects of high-velocity missiles on brain tissue'.
- In the United States, in the late forties, teenage boys were fed radioactive breakfast cereal, middle-aged mothers were injected with radioactive plutonium and prisoners had their testicles irradiated - all in the name of science, progress and national security reported *Time* magazine. These experiments were conducted from the 1940s through to the 1970s.
- During the fifties, sixties and seventies, the *New York Times* revealed, it was mandatory for all new students of both sexes at Harvard, Yale and other elite universities of the United States, to have themselves photographed naked for a huge project designed to demonstrate that 'a person's body, measured and analysed, could tell much about intelligence, temperament, moral worth and probable future achievements. The inspiration came from the founder of Social Darwinism, Francis Galton, who proposed such a photo archive for the British population'. From the outset, disclosed the paper, 'the purpose of these "posture photographs" was eugenic'. The accumulated data would be used to 'control and limit the production of inferior and useless organisms'. 'Some of the latter would be penalised for reproducing...or would be sterilised. But the real solution is enforced better breeding - getting those Exeter and Harvard men together with their corresponding Wellesley, Vassar and Radcliffe girls'. The biologist responsible for the project, W H Sheldon of Harvard, used the photographs to publish the *Atlas of Men*.

- Scientists have discovered a gene responsible for criminal behaviour reported the *Independent*. A few months earlier, we read that scientists had isolated a gene for homosexuality. The implication being that criminals and homosexuals are born not influenced by social or environmental factors. (The Independent, 15 Feb. 1995)

These revelations cast science in a radically different perspective. Developments such as these have led some thinkers to argue that modern science is socially and morally corrosive in the sense that it destroys the old certainties on which social life has depended for the past hundred millennia or so of human history (Appleyard, 1992, for example). Brian Appleyard argues that the sheer success of science - the overwhelming sense of power, of the ability to control the world, that it generates - has destroyed our ancient dependence on the spiritual world (Appleyard, 1992). It is the emotional content of our spiritual side, he insists, that makes us human. With the advent of modern science, we have lost that sense of self, or humanity, that makes us what we are, that creates for us a purpose in life.

“Science...is spiritually corrosive, burning away ancient authorities and traditions. It cannot really co-exist with anything. Scientists inevitably take on the mantle of the wizards, sorcerers and witch-doctors. Their miracle cures are our spells, their experiments our rituals.” (Appleyard, 1992, p.16)

What scientists actually do has been extensively examined by historians of science and sociologists of knowledge, producing a different set of definitions and explanations for science and challenging the view of science as an heroic objective adventure, above all concerns of culture and values. Thus, according to the historian Thomas S Kuhn (whose work is discussed more extensively in Chapter 1), science is nothing more than problem solving within a paradigm: a set of dogmas, beliefs and values. This is what most scientists do when they do ‘normal science’. When the paradigm is challenged and over-turned, ‘revolutionary science comes into being’ (Kuhn, 1962). The late Paul Feyerabend, a noted philosopher of science, thinks that there

is nothing special about science; indeed, there is no fundamental difference between art and science, for both lack a bedrock of well-founded theory, practice or empirical certainty (Feyerabend, 1975). There are no epistemological or methodological foundations for science, Feyerabend has argued and tried to demonstrate, that can command universal consent. Thus we can never hope to discover truth by scientific investigation. For historian and philosopher of science Jerome R Ravetz, science is an industry in which knowledge and power have coalesced, knowledge has been corrupted and become an instrument of control and domination (Ravetz, 1971, 1990). The proponents of the 'strong programme', a group of historians, sociologists and philosophers of science, located at the University of Edinburgh, describe science as a distinctively Western, imperialist phenomenon, concerned largely with social, political and cultural domination (Bloor, 1976, 1984). Robert Young, the Marxist critic of science, considers science to have nothing do with objectivity and neutrality: it is purely socially constructed. His classic essay is simply entitled 'science is social relations' (Young, 1977). For the sociologists Harry Collins and Trevor Pinch, 'science is a golem':

"A golem is a creature of Jewish mythology. It is a humanoid made by man from clay and water, with incantations and spells. It is powerful. It grows a little more powerful every day. It will follow orders, do your work, and protect you from the ever threatening enemy. But it is clumsy and dangerous. Without control, a golem may destroy its masters with its failing vigour...since we are using a golem as a metaphor for science, it is also worth noting that in the mediaeval tradition the creature of clay was animated by having the Hebrew 'EMETH', meaning truth, inscribed on its forehead - it is truth that derives it on. But this does not mean it understands the truth - far from it." (Collins & Pinch, 1993, pp.1-2)

Feminist scholar Sandra Harding considers science to be a sexist and chauvinist enterprise that promotes the values of white, middle class males (Harding, 1986). Ashis Nandy, one of the most respected Indian thinkers, has described science as a theology of violence (Nandy, 1988). It performs violence against the subject of knowledge, against the object of knowledge, against the beneficiary of knowledge and against knowledge itself. To noted Indian science journalist and traditional philosopher, Claude Alvarez, science is a recognisable 'ethnic (western) and

culture-specific (culturally entombed) project, one that is politically directed, artificially induced stream of consciousness invading and distorting, and often attempting to take over, the larger, more stable canvas of human perceptions and experience' (Alvarez, 1992). It is as universal as toothpaste manufactured in the West, just as exploitative in its economic imperialism, it can be used, and is often used, but can be replaced with a *muswak* from the neem tree, or dispensed with altogether at any time because it is still largely irrelevant to *life*.

All of these different definitions and perceptions of science tell us one thing for certain: *science is a contested territory*. The various contesting claims and counter-claims about the nature of science, all containing some aspect of truth, reveal science to be a highly complex and multilayered activity. No single and simple description of science can reveal its true nature; no romantic ideal can describe its real character; no sweeping generalisation can uncover its authentic dimensions. In particular, both the extreme positions of scientific fundamentalism and fundamentalist relativism are untenable.

The idea of scientists as dedicated hermit-like lone researchers is now dangerously obsolete. Nowadays, science is an organised, institutionalised and industrialised venture. The days when individual scientists, working on their own, and often in their garden sheds, made original discoveries are really history. Virtually all science today is big science requiring huge funding, large, sophisticated and expensive equipment and hundreds of scientists working on minute problems. As such, science has become a unified system of research and application, with funding at one end of the spectrum and the end-product of science, often technology, at the other. In this system, it is not always possible for us to see where the so-called 'pure' science ends and technology begins. Moreover, in the huge and complex system that is science, it is equally impossible to say where politics and social values cease and experience mediated by nature, hence some resemblance of objectivity, takes over. The whole system is one gigantic

continuum with countless feedback loops. The puritan scientists argue that while science may exist within social frameworks and depend on funding from government or political institutions, the actual cognitive formation is independent of all social and political considerations and depends exclusively on what can be seen in nature. Moreover, empiricism, the rules of evidence, testing for falsification and peer review distil out all value contents leaving pure objective reality for us all to perceive. This Weberian ideal, the requirement of *wertfreiheit* - the freedom from values or ethical neutrality - leading to separation of science and politics, just does not stand up to empirical evidence. Despite the brave attempts by the logical positivists of the Vienna Circle, most notably Popper (whose work was discussed in Chapter 1), historians and sociologists of science have demonstrated that almost from its inception in the heydays of Robert Boyle and the English Revolution, science has been embroiled with religion, politics and capitalism. Ironically, Popper's idealised portrayal of experimenting - which is itself now seen as an ideological construct - opened science to the inspection of history of science and sociology of knowledge. Thus, there is hardly an area of modern scientific inquiry that has not been shown to have an ideological, social and cultural content. Post-colonial writers have shown the intimate connection between the emergence of modern science in the West and the rise of the Empire, the evolution of scientific knowledge and the subjugation of the non-Western cultures and people (Kumar, 1991; Sangwan, 1991; Kochar, 1993; and Joseph, 1995, for example). Furthermore, anthropologists of science, like Knorr-Cetina (1981) and Bruno Latour (1979), have suggested that laws and facts of science are not so much objectively discovered as 'manufactured'. While we ought to be cautious about accepting the totally relativist position that nothing of particular significance happens in a laboratory except the social relationship of the scientists, we cannot altogether ignore the evidence from sociology and anthropology of science.

So where does this leave the heroic model of pure, value-free science? Largely discredited. Despite this a large number of scientists, like Wolpert (1992) and Richard Dawkins (1976,

1986), and the Muslim Nobel Laureate Abdus Salam (1986, 1991), zealously hold on to it. In contrast, the philosophical, historical, sociological and anthropological study of science has become highly sophisticated while, at the same time, becoming ever more deeply entrenched in extreme relativism. The epistemological and moral relativism of post-modern studies of science not only takes us towards absolute chaos but also leaves a few important questions unanswered. Why has science been so successful in bringing prosperity to Western civilisation? How is it possible for its results to be repeated across cultures? And the converse: why have different cultures, with different metaphysical axioms and social perceptions, produced universally valid scientific projects? The truth (however we describe it), as always, lies somewhere in the middle.

Considering that the modern world is largely a product of modern science and that science touches everyone's life, it is necessary for us all to understand how modern science is shaped, how its agenda is set, and how deeply (Western) values are embedded in it. We need to get involved with science and make it work for us: for our needs and requirements, reflecting our concerns and values, promoting the distributive justice and equality that we cherish. As Margaret Jacob points out,

“if more women and non-Western people had been involved in science at any given moment, its agenda would have been set quite differently. Most of its methods and practices and capacity for truth might look much like they do today, but the knowledge generated would have been on very different subjects, been expressed in quite different language, and in some cases been put into the service of very different (although not necessarily better) interests. Not least permitting greater access to science would further democratise its practices and generate more, not less, usable knowledge.” (Jacob, 1994, p.6)

The question is not simply of ‘greater access’ but actually shaping science based on different values and perceptions. From the Muslim viewpoint, it means shaping a science that is based on the values and metaphysical assumptions of Islam: what some have called ‘Islamic science’, but what should more accurately be referred to as ‘science in the context of Islam’, or ‘science

from the Islamic perspective'. The first steps towards a meaningful discussion of contemporary Islamic science is an appreciation of the part played by ideological and political concerns as well as values in the defining characteristics and development of modern science. Sue Lyle and Alyson Jenkins, for example, have succinctly declared that

“The social and political climate in which western science operates powerfully influences what research is done by determining what is valued and what is not. This also influences the ways in which science is applied, by politicians and industry, often to the detriment of the environment and people.” (ASE, 1991, introduction)

Their chapter on ‘Making Global Connections Through Science and Science Teaching’ offers examples of illustrating the value system which dominates western science and is the foundation of industrialised societies.

## 2.2 Science and Values

Values enter the system of science in a number of ways. The first point of entry is the selection of the problem to be investigated. The choice of the problem, who makes the choice and on what grounds, is the principle point of influence of society, political realities of power, prejudice and value systems on even the ‘purest’ science. Often, it is the source of funding that defines what problem is to be investigated. If the funding is coming from government sources then it will reflect the priorities of the government - whether space exploration is more important than health problems of inner city poor, or nuclear power should be developed further or solar energy. The private sector funding, mainly from multinationals, is naturally geared towards research that would eventually bring dividends in terms of hard cash. Some eighty percent of research in the United States is funded by what is called the ‘military-industrial complex’ and is geared towards producing both military and industrial applications. In the former Soviet Union, all research was funded and directed by the State.



Thus the practice of science, by and large, is regulated by the state. In some cases this can lead to obvious and transparent abuse: in the Third Reich, science was literally constructed and developed within the Nazi ideology. Our abhorrence of fascism leads us to dismiss the Nazi construction of science as inherently inferior. But as Alan Beyerchen has shown German science under Hitler was more than a match for science anywhere in Europe and North America. It not only promoted scientists of the stature of Heisenberg but also led him to ethical conduct that was diametrically opposite from the notion of science as a tool for betterment of humanity. Similarly, Soviet science too was ideologically constructed. In its most extreme form, it produced Lysenkoism in genetics; but on the whole, the ideological concern for big technologies meant an emphasis on the exact sciences. Both in the case of Nazi Germany and the Soviet Union, it is easy for us to see how state ideology directed and shaped science. However, the role of ideology in shaping science in the free and democratic world is not so apparent (Beyerchen, 1977).

But here too the link between ideology and science is just as strong. American science, for example, is tightly controlled by an alliance of the military, powerful multi-nationals and research universities. American militarism directs American science while American science propels American militarism: they define each other.

“Just as the technologies of the empire,” writes Stuart W Leslie, “defined the relevant research programs and conceptual categories for Victorian scientists and engineers, so the military-driven technologies of the cold war redefined the critical problems for the post-war generation of American scientists and engineers. Indeed, those technologies virtually redefined what it meant to be a scientist or an engineer. Whereas Vannevar Bush’s differential analyser - a pioneer analog computer - provided a tangible expression of the engineering values, educational practices, and critical problems of early twentieth-century science and engineering, another set of instrumental archetypes - including masers and lasers (for amplifying microwave and visible radiation), missile guidance systems, numerically or computer-controlled machine tools, and microwave radar - provides the texts for understanding the orientations of post-war science.” (Leslie, 1994, pp.209-210)

Devices and other equipment developed for the military not only provide new instruments for science but also shape the conceptual categories and tool kits of scientists. The computer, rocket launchers, the laser, microwave communication technologies and satellites were all developed for the 'security interest' of the United States and then became key research instruments in shaping and directing science. Instruments which appear to have purely scientific interests usually emerge from the 'Strategic Defense Initiative'. Leslie provides the following list of instruments that are direct outcomes of military research: the Hubble Space Telescope, the supersonic wind tunnels that were used in the design of successive generations of high-speed aircraft and ballistic missiles; the high-power klystrons that fuelled physics at Stanford; MIT's Whirlwind computer; the Gravity Probe B, which owed as much to military interests as in confirming Einstein's theory of general relativity; and transistor and integrated circuits. When the priority of the military shifts, the direction of science changes. Thus when the Pentagon decided to shift its emphasis from radio-controlled to guided missiles, science's model of the ionosphere altered from one envisioning it as a two-dimensional mirror to one viewing it as a three-dimensional medium. Often the discussion of an emerging field is framed within the discourse of war. Just as Quantum physics emerged coincidentally from the concern for war, defeat, rationality, and "the decline of the West" in Weimar Germany, so, too, the discourse of Cold War shaped American physics, aeronautics, materials science, electrical engineering and other academic fields. Electrical engineering provides an example of how power politics shapes the character of scientific knowledge. Military funding of research laboratories, such as MIT's Research Laboratory of Electronics and the Stanford Electronics Laboratories, ensured that they made defense electronics the leading edge of academic research; in the process, writes Leslie, 'they blurred conventional distinctions between science and engineering, basic and applied research, unclassified and classified material, sponsored research and education' (Leslie, 1994). As a result, the emphasis shifted from the pre-war curriculum of alternating current, radio, and high-voltage power transmission to problems in microwave and solid-state electronics,

communications theory and plasma physics. Military oriented research and teaching feed each other engendering a system that is totally geared towards military goals: 'Professors teach what they know. They write textbooks about what they teach. What they know that's new comes mainly from their own research. It is hardly surprising, then, that military research in the university leads to military-centred undergraduate curricula' (Leslie, 1994). Thus American science, which dominates the world and can be considered be the practice of science everywhere, is deeply linked to a military culture. Its disciplinary paradigms, its experimental practices, its research and teaching programmes, reflect the security interests of the United States. Considerations of the deep involvement of science with the military ideology of nation states had led Ashis Nandy to describe 'science as reason of state' (Nandy, 1988).

Ideological concerns are also sometime brought to bear on the interpretation of scientific discoveries. Scientific findings often raise moral questions. The moral debate around Social Darwinism provides one example of how science is put in the service of a particular ideology. In the nineteenth century, social philosophers developed their ideas from the disconcerting revelations of Wallace and Darwin projecting their own views of class, wealth, race, sex, social justice and progress on their theories: "Spencer justified laissez-faire capitalism by equating economic competition with natural selection, and he drew upon a revised Malthusianism to explain why poverty was unavoidable. Engels fought the trend by pointing out how economic activity intervenes in selection, and how, as Darwin himself had recognised, co-operative behaviour can enhance survivability. Comte represented himself as siring sociology out of the biological sciences. And later, on an openly Darwinian theme, Galton founded the eugenics movement' (Lowrance, 1985).

However, ideological and political influences enter science not just in terms of funding, which defines the areas selected for research, or in the interpretation of discoveries, but also in

what is actually seen as a problem, what questions are asked and how they are answered. For example, cancer rather than diabetes may be seen as a problem even though they may both claim the same number of victims. Here both political and ideological concerns, as well as public pressure, can make one problem invisible while focusing attention on another. Moreover, if, for example, the problem of cancer is defined as finding a cure then the benefits of the scientific research accrue to certain groups, particularly the pharmaceutical companies. But if the function of scientific research is seen as eliminating the problems of cancer from society, then another group benefits from the efforts of research: the emphasis here shifts to investigating diet, smoking, polluting industries and the like. Similarly, if the problems of the developing countries are seen in terms of population, then research is focused on reproductive systems of Third World women, methods of sterilisation and new methods of contraceptives. However, if poverty is identified as the main cause of the population explosion then research would take a totally different direction: the emphasis would have to shift to investigating ways and means of eliminating poverty, developing low cost housing, basic and cheap health delivery systems and producing employment generating (rather than profit producing) technologies. The benefits of scientific research would go to the Third World poor rather than Western institutions working on developing new methods of contraceptives and companies selling these contraceptives to developing countries. Thus not just the selection of problems but also framing of problems in a particular way are based on value criteria.

It can be argued that the ideological and political factors are external to science. That within science, the scientific method ensures neutrality and objectivity by following a strict logic - observation, experimentation, deduction and value-free conclusion. But scientists do not make observations in isolation. All observations take place within a well defined theory. The observations, and the data collection that goes with them, are designed either to refute a theory or provide support for it. And theories themselves are not plucked out of the air. Theories exist

within paradigms - that is a set of beliefs and dogmas. The paradigms provide a grand framework within which theories are developed and make sense and observations themselves have validity only within specific theories. Thus, all observations are theory laden, theories themselves are based on paradigms which in turn are burdened with a culture baggage. All of which raises the question: can there ever be such things as value neutral, 'objective facts'? The notion that scientific 'facts' are a reflection of some reality out there is now being increasingly questioned: it is not clear whether a mere mathematical description of a phenomenon actually corresponds to some reality. Does the recently discovered subatomic particle, the top quark, which 'exists' for a mere hundredth of a billionth of a billionth of a second (long enough for 900 hundred scientists working on the problem to measure its existence) after protons are smashed together at high speed in a particle accelerator, actually exist in reality or is it simply an elegant mathematical construction that works in certain models? Similar questions have been raised about the 'truth' of scientific laws. Science uses two types of laws: phenomenological and theoretical; the distinction is rooted in epistemology. Phenomenological laws are things which we can, at least in principle, observe directly, whereas theoretical laws can be known by inference. Theoretical laws are supposed to explain phenomenological laws; and physicists have transformed theoretical laws to fundamental laws, the assumption being that they describe some basic reality in nature. In science, phenomenological laws are meant to describe and they succeed reasonably well; but fundamental equations are meant to explain, and paradoxically enough, the cost of explanatory power is descriptive adequacy. Really powerful explanatory laws of the sort found in theoretical physics do not state the truth. They are arrived at by a series of approximations: whenever theory tests reality, a host of approximation and adjustment is required. And as Nancy Cartwright, the Stanford physicist and philosopher has argued, 'the application of laws to reality by a series of *ad verum approximation* argues for their falsehood, not their truth' (Cartwright, 1993). The fundamental laws of science do not govern objects in reality, they govern only objects in models - and the models themselves are artificial construction for the sake of convenience.

Value judgements are also at the very heart of a common element of scientific technique: statistical inference. When it comes to measuring risks, scientists can never give a firm answer. Statistical inferences cannot be stated in terms of 'true' or 'false' statements. When statisticians test a scientific hypothesis they have to go for a level of 'confidence'. Different problems are conventionally investigated to different confidence-limits. Whether the limit is 95 or 99.9 per cent depends on the values defining the investigations, the costs and weight placed on social, environmental or cultural consequences. In most cases, the importance given to social and environmental factors determine the limits of confidence and the risks involved in a hazardous scientific endeavour. For example, when a dangerous chemical plant is placed in an area with an aware and politically active citizenry the risks are worked out to a high level of confidence. However, when toxic chemical plants are located in a region where the citizens themselves are ignorant of the dangers and do not command political power, the confidence levels are much more relaxed. The people of Bhopal and Chernobyl know this to their cost. Most scientists make expert value-laden decisions for and in the name of the public. Consider, for example, geologists: what could be less social and value free than rocks? But geologists have to make seismic assessments and take decisions for locating hydroelectric or nuclear power plants, advise on beach protection, municipal building codes, transnational water resources, seabed mining, and strategic minerals supply, and lead projects on causes of acidification of lakes and on underground disposal of radioactive water. The confidence limits of each decision would be largely based on value criteria.

But it is not just in its institutions and method that science is value laden. The very assumptions of science about nature, universe, time and logic are ethnocentric. In modern science, nature is seen as hostile, something to be dominated. The Western 'disenchantment of nature' was a crucial element in the shift from the medieval to the modern mentality, from feudalism to capitalism, from Ptolemaic to Galilean astronomy, and from Aristotelian to Newtonian physics.

In this picture, 'Men' stand apart from nature, on a higher level, ready to subjugate and 'torture' her, as Francis Bacon declared, in order to wrestle out her secrets. This view of nature contrasts sharply with how nature is seen in other cultures and civilisations. In Chinese culture, for example, nature is seen as an autonomous self-organising entity which includes humanity as an integral part. In Islam, nature is a trust, something to be respected and cultivated and people and environment are a continuum - an integrated whole. The conception of laws of nature in modern science drew on both Judeo-Christian religious beliefs and the increasing familiarity in early modern Europe with centralised royal authority, with royal absolutism. The idea that the universe is a great empire, ruled by a divine logos, is, for example, quite incomprehensible both to the Chinese and the Hindus. In these traditions the universe is a cosmos to which humans relate directly and which echoes their concerns. Similarly, while modern science sees time as linear, other cultures view it as cyclic as in Hinduism or as a tapestry weaving the present with eternal time in the Hereafter as in Islam. The metaphysical assumptions of modern science make it specifically Western in its main characteristics.

The metaphysical assumptions of modern science are reflected in its contents. For example, certain laws of science, as some Indian physicists claim, are formulated in an ethnocentric and racist way. The Second Law of Thermodynamics, so central to classic physics, is a case in point: due to its industrial origins, argues C V Seshadri (1993), the Second Law presents a definition of efficiency that favours high temperatures and the allocation of resources to big industry. Work done at ordinary temperature is by definition inefficient. Both nature and non-Western world become losers in this new definition. For example, the monsoon, transporting millions of tons of water across a subcontinent is 'inefficient' since it does its work at ordinary temperatures. Similarly, traditional crafts and technologies are designated as inefficient and marginalised. In biology, social Darwinism is a direct product of the laws of evolutionary theories. Genetic research appears to be obsessed with how variations in genes account for difference

among people. Although we share between 99.7 and 99.9 per cent of our genes with everyone, genetic research has been targeted towards the minute percentage of genes that are different in order to discover correlations between genes and skin colour, sex or 'troublesome' behaviour. Enlightened societal pressures often push the racist elements of science to the sidelines. But the inherent metaphysics of science ensures that they reappear in new disguise. Witness how eugenics keeps reappearing with persistent regularity. The rise of IQ tests, behavioural conditioning, and socio-biology are all an indication of the racial bias inherent in modern science.

Given the Eurocentric assumptions of modern science, it is not surprising that the way in which its benefits are distributed and its consequences are accounted for are themselves ethnocentric. As Sandra Harding (1993) has argued, when scientific research improves the military, agriculture, manufacturing, health or even the environment, the benefits and expanded opportunities science makes possible are distributed predominantly to already privileged people of European descent, while the costs are dumped on the poor, racial and ethnic minorities, women, and people located at the periphery of global economic and political networks: this is the racial economy of science. Science in developing countries has persistently reflected the priorities of the West, emphasising the needs and requirements of middle class western society, rather than the wants and conditions of their own society. In over five decades of science development, most of the Third World countries have nothing to show for it. The benefits of science just refuse to trickle down to the poor.

But modern science is not only culturally biased towards the West: it represents the values of a particular class and gender in Western societies. As feminist scholars have shown, science in the West has systematically marginalised women. Women, on the whole, are not interested in research geared towards military ends, or torturing animals in the name of progress or working on machines that put one's sisters out of work. But more than that, even the least



likely fields and aspects of science bear the fingerprints of androcentric projects. Physics and logic, the prioritising of mathematics and abstract thought, the so-called standards of objectivity, good method and rationality - feminist critique has revealed androcentric fingerprints in all! For example, in the mechanistic model of early modern astronomy and physics, in modern particle physics, and in the coding of reason as part of ideal masculinity. The focus on quantitative measurements, variable analysis, impersonal and excessively abstract conceptual schemes is both a distinctively masculine tendency and one that serves to hide its own gendered character. Science has tried to hide its own masculine nature in other ways, by, for example, making women themselves objects in scientific investigation. It wasn't entirely accidental that sexology became a major science at the same time as women in the West were fighting for the vote and equal rights in education and employment! A number of studies have shown that scientific work done by women is invisible to men even when it is objectively indistinguishable from men's work (see, for example, McNeil, 1987). Thus, it appears that neither social status within science nor the results of research are actually meant to be neutral or socially impartial. Instead, the discourse of value-neutrality, objectivity, social impartiality appears to serve projects of domination and control.

The history of science bears this out. The evolution of Western science can be traced back to the period when Europe began its imperial adventure. Science and empire developed and grew together each enhancing and sustaining the other. In India, for example, European science served as a handmaiden to colonialism. The British needed better navigation so they built observatories and kept systematic records of their voyages. The first sciences to be established in India were, not surprisingly, geography and botany. Western science progressed primarily because of military, economic and political power of Europe, focusing on describing and explaining those aspects of nature that promoted European power, particularly the power of the upper classes. The disinterested commitment of European scientists to the pursuit of truths

had little to do with the development of science. The subordination of the blacks in the ideology of the black 'child/savage' and the confinement of the white women in the cult of 'true womanhood' emerged in this period and are both a by-product of the Empire. While the blacks were assigned animal and brutish qualities the white women were elevated and praised for their morality. While the blacks were segregated and enslaved, the women were placed in narrow circles of domestic life and in conditions of dependency. Racist and androcentric evolutionary theories were developed to explain human behaviour and canonised in the history of human evolution. The origins of Western, middle class social life, where men go out to do what men have to do, and women look after the babies and work in the kitchen, are to be found in the bonding of 'man-the-hunter'; in the early phases of evolution women were the gatherers and men went out to bring in the beef. Now this theory is based on little more than the discovery of chipped stones that are said to provide evidence for the male invention of tools for use in the hunting and preparation of animals. However, if one looks at the same stones with different cultural perceptions, say one where women are seen as the main providers of the group - and we know that such cultures exist even today - you can argue that these stones were used by women to kill animals, cut corpses, dig up roots, break down seed pods, or hammer and soften tough roots to prepare them for consumption. A totally different hypothesis emerges and the course of the whole evolutionary theory changes.

Thus the cultural, racial and gender bias of modern science can be easily distinguished when it is seen from the perspective of non-Western cultures, marginalised minorities and women. The kind of questions science asks when seeking to explain nature's regularities and underlying causal tendencies, the kind of data it generates and appeals to as evidence for different types of questions, the hypothesis that it offers as answers to these questions, the distance between evidence and the hypothesis in each category, and how these distances are traversed - all have the values

of the white, middle class men embedded in them. Put simply, this implies a relativism in science as in any other sphere of human knowledge.

Given the evidence for deep ideological, political and cultural fingerprints in modern science, why do scientists still insist on the neutrality for their enterprise? Indeed, some scientists have even suggested that all the evidence gathered from historical, philosophical, sociological and anthropological studies of science is nothing more than a conspiracy against science of left-wing academics! The myth of neutral science not only ensures the power and prestige of science in society but enables it to perform an omnipotent function in shaping the modern world. The idolisation and mystification of science, the insistence on its value neutrality and objectivity, is an attempt not only to direct our attention away from its subjective nature but also from the social and hierarchical structure of science. Whenever we think of 'the scientists' we imagine white men in white coats: the sort of chaps we see in advertisements for washing powder and skin care preparations, standing in a busy laboratory behind a Bunsen burner and distillation equipment telling us how the appliance of science has led to a new and improved soap or cold cream. This view of the scientists is not far from reality. True power in science belongs to white, middle aged, men of upper classes. Everyone else working in science - women, minorities, and third world researchers, even white men of lower classes are actually basically rank and file laboratory workers. The social hierarchy within science by and large preserves absolute social status, the social status scientific workers hold in the larger society. The people who make decisions in science, who decide what research is to be done, what questions are going to be asked, and how the research is going to be done are a highly selective, tiny minority. These people have the right cultural background, the contacts to get the necessary appointments and then further contacts to secure funding for their research projects. The actual execution of scientific research, the grinding and repetitive laboratory work, is rarely done by the same person who conceptualises that research and even the knowledge of how to conduct research is rarely

possessed by those who actually do it. This is why the dominant (Western) social policy agendas and the conception of what is significant among scientific problems are so similar. This is why the values and agendas important to white, middle class men pass through the scientific process to emerge intact in the results of research as implicit and explicit policy recommendations. This is why, modern science has become an instrument of control and manipulation of non-Western cultures, marginalised minorities and women.

To appreciate the social structure of science, consider the fact that scientists at the National Research Centre in Cairo, the largest research establishment in Africa, work largely on American projects for which Egypt is paid in kind by wheat! Both China and India have huge scientific manpower yet they are totally on the margins of global science. India, with its relatively well developed scientific infrastructure, including scientific laboratories, universities, a network of scientific journals, and large number of scientists and researchers, is the Third World's scientific superpower. Both countries have a long history of scientific research and both have achieved considerable success: both have advanced physics facilities, growing high-tech industrial base and universities of international standards. But both are located firmly on the periphery of science because science is highly centralised and those who control and manage it are concentrated in a small number of industrialised countries. The scientific communications system is also centralised and controlled by the major research producing nations. While there are between 60,000 and 100,000 scientific journals world-wide, only about 3,000<sup>\*</sup> are indexed by the Institute for Scientific Information (ISI), which keeps track of 'significant', internationally circulated science: most of the science that happens in non-Western countries is considered irrelevant and unworthy of attention. It is publications that are indexed by institutions like ISI that communicate the major findings of scientific disciplines, that are read by scientists throughout the world, and that are cited and used by other scientists for their own work. Most of these journals are edited by senior scientists in America and Europe who guard their territory jealously and ruthlessly. It is these

individuals who define what is science and what is of interest globally. Scientists with different interests or concerns find it almost impossible to be published in these journals. Data bases and information systems, so important for scientific work, are also located in the industrialised countries who own the information as well as control access to it. This system not only ensures that science in non-Western countries remains on the periphery but actually transforms it into an appendage of the western system of science. Much of the science in the Third World is led by scientists who were educated in the West. For example, in the early 1990s, more than 10,000 scientists from China and about 60,000 from India obtained their doctorates from the United States. When these scientists return to their homelands, having imbibed particular models of science and research, they promote the same research with the same priorities and emphasis. Thus, science in the Third world serves the needs and goals of industrial societies - albeit in a rather subservient and marginal role. The social structure of science even kept the Soviet Union, despite the fact that it built the world's largest scientific and technical establishment, firmly on the margins.

\* Cited in unpublished document by  
COMSTECH (1995), Islamabad Pakistan  
(International Science Conference, April 1995) .

So, where ever we look in science, from its funding to its methodology, facts and laws to its control and management, we see values in action. In fact, even if we were to ignore all other arguments and evidence, the very claim of modern science to be value-free and neutral would itself mark it an ethnocentric and a distinctively western enterprise. Both claiming and maximising cultural neutrality is itself a specific western cultural value: non-Western cultures do not value neutrality for its own sake but emphasise and encourage the connection between knowledge and values. By deliberately trying to hide its values under the carpet, by pretending to be neutral, by attempting to monopolise the notion of absolute truth, Western science has transformed itself into a dominant and dominating ideology.

To make science work for ourselves, we need to consciously strive towards shaping a science that is an embodiment of our norms and values. The function of the debate on a contemporary Islamic science/science in the context of Islam is to explore how this can be done.

### 2.3 Islamic Science/Science in the Context of Islam

The debate on meaning, nature and characteristics of a contemporary Islamic science really started when a cover story on science in the Muslim world was first published in *Nature* (Sardar, 1980). In the seventies, the rise of OPEC, the Iranian revolution and a growing consciousness in Muslim societies of their cultural identity led many scientists and academics as well as institutions to emphasise the distinctive scientific heritage of Islam. This was discovered as a result of a systematic study of the Muslim world, from Morocco to Indonesia, looking at research and evaluating the problems and potentials of Muslim countries: the results emerged as Science, Technology and Development in the Muslim World (Sardar, 1977). The reflections on the history of Islamic science generated a question of contemporary relevance: how can modern Muslim societies rediscover the spirit of Islamic science as it was practised and developed in history? This question was put, on behalf of *Nature*, to Muslim scientists and science educationalists in several countries. A year later, in 1980, Sardar travelled, once again, throughout the Muslim world with the support of New Scientist and wrote another cover story, followed by a number of essays exploring and extending the theme of Islamic science. These articles and essays led to a number of international seminars and conferences - most notably the series of seminars on 'Science and Technology in Islam and the West: A Synthesis' held under the auspices of the International Federation of Institutes of Advance Studies in Stockholm (24-7 September 1981) and Granada (31 May-2 June 1982); the 'International Conference on Science in Islamic Polity - Its Past, Present and Future' backed by Organisation of Islamic Conference and held in

Islamabad, Pakistan (19-24 November 1983); and 'The Quest for a New Science' Conference organised by the Muslim Association for the Advancement of Science (MAAS), in Aligarh, India (8-11 April 1984) - where ideas relating to Islam and science were explored further. The conferences provided a launch-pad for the debate and revealed a great deal of confusion around the whole notion of Islamic science and its meaning and relevance to contemporary times.

That the idea of a contemporary Islamic science/science from the Islamic perspective is fraught with difficulties was recognised by all those who participated in the early discussions. Even the meaning and relevance of the term itself came into question. As Ravetz has pointed out, the term 'science' has come to mean a specifically modern, European and secular view of the world. Thus, 'Islamic science' appears as a self-contradictory concept. But

"this would be the case with any sort of science with a religious description; thus even though modern science was created with a Christian culture, the term 'Christian science' is now firmly associated with a belief system that all scientist would strenuously reject. Those whose priority is to Islam rather than to the scientific worldview must therefore reckon with the consequences of a half millennium of history in this sphere as in others. The result of this heritage is that a double difficulty faces anyone who would construct, or reconstruct, a characteristically Islamic science. First, science as we now understand it is historically rooted in Christianity; and second, its practical consequences in the spheres of ideas have been to render all religion irrelevant." (Ravetz, 1991, p.269)

These problems were anticipated; as were the objections of conventional positivists like the noble laureate, Abdus Salam. Relativism in science is, of course, anathema to positivists. However, positivist defense of the purity of Western science has now turned into a kind of scientific fundamentalism as illustrated by the writings of Parvez Hoodbhoy (1991). Perhaps, recent developments in eugenics, patenting of genes as a result of the Human Genome Project, and the efforts in theoretical physics to produce a Theory of Everything that can be proudly displayed on a T-shirt and the emergence of complexity, would change the perceptions of the

positivists. Anyhow, how long can the positivists ignore the advances in philosophy and history of science and sociology and anthropology of knowledge?

What came as a total surprise was the influence of the ontological tendency on the debate. For many Muslim scientists and scholars, Islamic science amounted to little more than the study of the nature of things in an ontological sense. Two main strands emerged from this approach: the mystical and the apologetic; the latter I have dubbed 'bucallism'. In the mystical perception, the material universe is studied as an integral and subordinate part of the higher levels of existence, consciousness and modes of knowing. Thus, here we are talking about science not as a problem solving enterprise, but more as a mystical quest for understanding the Absolute. In this universe, conjecture and hypothesis have no real place; all inquiry must be subordinate to the mystical experience. This school of thought, led by Hossein Nasr (1993), Iranian scholar and follower of the esoteric sect of Fritjof Schoun, has a hypnotic effect on the minds of many proponents of Islamic science. Nasr also has a very specific position on Islamic science in history. For him, all science in the Muslim civilisation was 'sacred science', a product of a particular mystical tradition - namely the tradition of gnosis, stripped of its sectarian connotations and going back to the Greek neo-platonists. In his historical works, Nasr has concentrated exclusively on such matters as the occult, alchemy and astrology at the expense of the vast amount of work done on exact sciences in an attempt to show that Islamic science in history was largely 'sacred science'. (Not surprisingly, Nasr's rewriting on Islamic history of science have been strongly refuted not just by Muslim historians of science like Faut Sagzin and Ahmad al-Hassan but also by a string of Western historians such as David King and Donald Hill.) To Nasr and his followers, like Osman Bakr, 'traditional science' does not mean science as it has existed in Muslim tradition and history, but esoteric products produced within the tradition of Islamic mysticism or Sufism. Traditional science is science sacra, the Science of Ultimate Reality, as thought by Sufi masters and mystics of other traditions. The goal of Islamic



science today, they argue, is to rediscover the classical Islamic esoteric traditions and its sacred nature (see Loo, 1996).

Bucaillism is a combination of religious and scientific fundamentalism. Bucaillists try to legitimise modern science by equating it with the Quran or to prove the divine origins of the Quran by showing that it contains scientifically valid facts. Bucaillism grew out of The Bible, the Quran and Science by Maurice Bucaille (1976), a respected French surgeon. Bucaille examines the holy scriptures in the light of modern science to discover what they have to say about astronomy, the earth, animal and vegetable kingdoms. He finds that the Bible does not meet the stringent criteria of modern knowledge. The Quran, on the other hand, does not contain a single proposition at variance with the most firmly established modern knowledge, nor does it contain any of the ideas current at the time on the subjects it describes. Furthermore, the Quran contains a large number of facts which were not discovered until modern times. The book, translated into almost every Muslim language from the original French, has spawned a whole genre of apologetic literature (books, papers, journals) looking at the scientific content of the Quran. From relativity, quantum mechanics, big bang theory to the entire field of embryology and much of modern geology has been 'discovered' in the Quran. Conversely, 'scientific' experiments have been devised to discover what is mentioned in the Quran but not known to science - for example, the programme to harness the energy of the jinn; or the project backed by World Muslim League to prove the validity of the famous fly 'hadith' which states that if one wing of a fly falls into something you are drinking dip the other one as well for it may contain the antidote. This sort of attempt to put science in the service of ontological causes is based on an acute inferiority complex which demands that the superiority of the Quran must be demonstrated by scientific validity and on the mistaken understanding of the ability and power of science. Unfortunately, this is the dominant perception of the relationship between science and Islam in the Muslim world.

So what do we actually mean by Islamic science? The science part of the term here emphasises the fact that we are talking about science: as an organised, systematic and disciplined mode of inquiry based on experimentation and empiricism that produces repeatable and applicable results universally, across all cultures. Although science, in our perspective, incorporates the rich heritage of Muslim civilisation, we are essentially talking about contemporary science. Where work, theories and results of earlier Muslim scientists are incorporated in the contemporary venture, they have to be updated to the level of current thought. The Islamic element of the term suggests that values and assumptions shaping this science are those of the worldview of Islam. However, we are not talking about 'Islamisation' of science as though Islam was some sort of boot polish which is used to put an Islamic gloss on science. What we are concerned with are the universal values of Islam that emphasise justice, unity of thought and ideas, a holistic approach to the study of nature and social relevance of intellectual and scientific endeavour. In this framework, fragmentation, meaningless and endless reduction and appropriation of god-like powers, or monopoly of truth and suppression of other forms of knowledge are shunned. At this juncture, the nature of what is meant by Islamic science would be further clarified by stating Munawar Ahmad Anees' categories of what it is not:

1. Islamized science, for its epistemology and methodology are the products of Islamic worldview that is irreducible to the parochial Western worldview.
2. Reductive, because the absolute macroparadigm of tawheed links all knowledge in an organic unity.
3. Anachronistic, because it is equipped with future-consciousness that is mediated through means and ends of science.
4. Methodologically dominant, since it allows an absolute free-flourishing of method with the universal norms of Islam.
5. Fragmented, for it promotes polymathy in contrast with narrow disciplinary specialisation.

6. Unjust, because its epistemology and methodology stand for distributive justice with an exacting societal context.
7. Parochial, because the immutable values of Islamic science are the mirror images of the values of Islam.
8. Socially irrelevant, for it is 'subjectively objective' in thrashing out the social context of scientific work.
9. Bucaillism, since it is a logical fallacy.
10. Cultish, for it does not make an epistemic endorsement of Occult, Astrology, mysticism and the like. (Anees, 1984, pp.16-17)

To begin with this perspective changes our approach to science from the conventional secular to an Islamic attitude. The Islamic approach to science is to recognise the limitations of human reason and human mind and acknowledge that all knowledge comes from God. This was the goal of the 'science in Islamic polity' debate that began with the First International Conference on Science in Islamic Polity (19-24 November 1983). Within an Islamic polity - that is an idealised 'Islamic state' - the principles and injunctions of Islam which are the basis of the state, it was argued, would automatically guide science in the direction of Islamic values. The individual Muslim scientists would also bring his or her own values to bear on their work. The 'Statement on scientific knowledge seen from the Islamic perspective', issued by the Conference states that science is one way humanity seeks 'to serve the Supreme Being by studying, knowing, preserving and beautifying His creation'. The Islamic framework seeks a 'unifying perspective, combining the pursuit of science and the pursuit of virtue in one and the same individual'. The 'Islamabad Declaration' also called for the creation of 'the Islamic science and technology system' by the end of the century. Although this is the essential first step, there are a number of problems with this perspective. Perhaps the major problem is the definition of an Islamic polity: we do not really know what constitutes a contemporary Islamic polity. The examples before us of states

that claim to be 'Islamic' hardly provide us with confidence: Saudi Arabia, Iran, the Sudan and Pakistan. It seems that the label Islamic is being used here to justify authoritarianism, naked oppression, suppression of dissent and criticism and state violence against the people. How can science, any science, develop in such states? Moreover, apart from the fact that the emphasis on Islamic values in this perspective has remained largely at the level of rhetoric, science is still seen in similar terms to those of the Western paradigm as neutral and value free. Not surprisingly, much of the work done at the national and international level within the framework of 'Islamic conference Standing Committee on Scientific and Technological Cooperation' (COMSTECH), has been very conventional and concerned largely with nuclear physics, biotechnology and electronics. There is, for example, no real concern with building indigenous science, identifying areas of national concerns and needs, (science education in particular) or changing the direction of science towards the principles of Islam or the societal needs of Muslims. Replacing 'nature' with Allah in science textbooks may provide a psychological balm for our inferiority complex but it does not solve any real problems.

In contrast, both the Ijmalis (referred to in Chapter 1), a group of independent scholars and thinkers who have championed a future oriented critique of contemporary Muslim thought, and the *Aligarh* school, which has evolved around the Center for Studies on Science in Aligarh, India, have argued that the practice of science must change in Muslim countries if a contemporary Islamic approach to science is to have any meaning. The Ijmalis emphasise the 'repulsive facade' of the metaphysical trappings of Western science, the arrogance and violence inherent in its methodology, and the ideology of domination and control which has become its hallmark. These things, claim the Ijmalis, are inherent both in the assumptions of Western science as well as its methodology. Thus attempts to rediscover Islamic science must begin by a rejection of both the axioms about nature, universe, time and humanity as well as the goals and direction of Western science and the methodology which has made meaningless reductionism and objectification of

nature its basic approach. But science in this framework is not an attempt to reinvent the wheel; it amounts to a careful delineation of norms and values within which scientific research and activity is undertaken. At the Stockholm Seminar in 1981, Muslim scientists identified a set of fundamental concepts of Islam which should shape the science policies and scientific activity of Muslim societies. (See Chapter 1, Fig. 1.5, for a diagrammatic representation of these concepts.)

The concepts generate the basic values of Islamic culture and form a parameter within which an ideal Islamic society progresses. There are ten such concepts, four standing alone and three opposing pairs: tawheed (unity), khalifah (trusteeship), ibadah (worship), ilm (knowledge), halal (praiseworthy) and haram (blameworthy), adl (social justice) and zulm (tyranny) and istislah (public interest) and dhiya (waste). When translated into values, this system of concepts embraces the nature of scientific inquiry in its totality: it integrates facts and values and institutionalises a system of knowing that is based on accountability and social responsibility. How do these values shape scientific and technological activity? Usually, the concept of tawheed is translated as unity of God. It becomes an all-embracing value when this unity is asserted in the unity of humanity, unity of person and nature and the unity of knowledge and values. From tawheed emerges the concept of khilafah: that mortals are not independent of God but are responsible and accountable to God for their scientific and technological activities. The trusteeship implies that 'man' has no exclusive right to anything and that we are responsible for maintaining and preserving the integrity of the abode of our terrestrial journey. But just because knowledge cannot be sought for the outright exploitation of nature, one is not reduced to being a passive observer. On the contrary, contemplation (ibadah) is an obligation, for it leads to an awareness of tawheed and khalifah; and it is this contemplation that serves as an integrating factor for scientific activity and a system of Islamic values. Ibadah, or the contemplation of the unity of God, has many manifestations, of which the pursuit of knowledge is the major one. If scientific enterprise is an act of contemplation, a form of worship, it goes without saying that it cannot

involve any acts of violence towards nature or the creation nor, indeed, could it lead to waste (dhiya), any form of violence, oppression or tyranny (zulm) or be pursued for unworthy goals (haram); it could only be based on praiseworthy goals (halal) on behalf of public good (istislah) and overall promotion of social, economic and cultural justice (adl). Such a framework, argue the Ijmalis, propelled Islamic science in history towards its zenith without restricting freedom of inquiry or producing adverse effects on society. When scientific activity was guided by the conceptual matrix of Islam, it generated a unique blend of ethics and knowledge. It is this blend - which produces a distinctive philosophy and methodology of science - that distinguishes Islamic science from other scientific endeavours. Rediscovering a contemporary Islamic science, argue the Ijmalis, requires using the conceptual framework to shape science policies, develop methodologies, and identify and prioritise areas for research and development. (This position is more extensively discussed in Sardar, 1989). Of course, other concepts and values may be brought into play in shaping a contemporary Islamic science : the ten concepts suggested are not meant to be exhaustive; they provide a minimal framework within which scientific inquiry must take place. The Aligarh School has added a number of other concepts to this framework, for example, akhira (accountability in the Hereafter) and have explored the relationship between iman (acceptance of belief) and ilm at length. However, the point is that Islamic concepts and values lead to a radical change in the direction and methods of science from the dominant style and practice of science. Imagine a biology without vivisection or animal experimentation; or physics based on synthesis rather than reduction; materials research based on local and traditional materials; medicine incorporating the wealth of indigenous traditions: research and development focused on indigenous problems rather than prestige science and on empowering the populace rather than marginalising or victimising them. Only by developing science policies within the framework of the fundamental concepts of Islam, bringing these values to the level of the laboratory, and recognising the complexity of the issues and the difficulties involved in solving

the problems generated by Western science, can we develop a contemporary relationship between Islam and science.

Both Bucaillism and the mystical fundamentalism has fragmented the debate on Islamic science drawing it away from pragmatic and practical concerns. As Andrew Jamison has pointed out, the attempts to develop an Islamic science during the last fifteen years have repeated the same process and mistakes as the efforts to develop a ‘science for the people’ went through in the early 1970s: ‘in both cases, a critical identification of problems leads to an overly ambitious formulation of an alternative that has proved impossible to realise in practice. While the alternative becomes ever more extreme and absolute in terms of rhetoric, it thus fails to solve the particular problems that were initially attributed to Western science’ (Jamison, 1994). While there is dire need for more thorough explorations on the theoretical framework for Islamic science, it is also necessary for those concerned with Islamic science to turn their attention towards pragmatic policy and methodological work. So, how do we proceed from here?

## 2.4 Rediscovering an Intellectual Heritage

Perhaps, the most immediate need that the Islamic science movement faces is that of defragmentation. Without some theoretical consistency the Islamic science project will continue to be trapped in meaningless ontological discussions that have no real solutions. We need to separate the thought of Islamic science from what Parvez Manzoor has described as its ‘unthought’:

“One of the great unthought of our discourse is the relationship between the traditional Sufi metaphysics and the knowledge-generating societal activity that we mean by Islamic science. Given the fact that the task of delineating the metaphysics of Islamic science has been appropriated by the mystically-minded Muslim intellectuals, something which, perhaps, has been instrumental in stifling

growth of a societal and empirical outlook - the *sine quo non* of any 'scientific' perception - our discourse cannot be sustained by this ahistorical, asocietal epistemology any longer." (Manzoor, 1989, p.55)

A similar break is needed from the unthought of modern science: all pretence to the neutrality of science, along with the notion that science is the pursuit of some romantic truth, must now be abandoned. There were always problems with the assertion that the goal of science is to generate truth since one of the hallmarks of science - its claims to scientific objectivity - is that results of its inquiry must always be seen to be open to revisions in the face of new, contradictory empirical evidence. In post-Popper days, it was accepted that no empirical observation could prove a hypothesis true; it could only prove it false. But the ideal of falsification too is now in difficulties. Both historians and sociologists have shown that the scientific establishment tends to be stubborn when faced with evidence that refutes dominant theories: 'young theories must be retained in the face of occasional or even frequent falsifying observations: favoured older theories are usually retained until they are forced into retirement by the scientific community's shift in allegiance to an alternative; any theory can always be retained as long as its defenders hold enough institutional power to explain away potential threats to it' (Harding, 1994). When the ideal of falsification has itself been shown to be false, what use is the concept of truth in science? The whole notion of truth in science is

"inextricably linked to objectivism and its absolutist standards. 'Less false' claims are all the procedures of the sciences (at best) can generate: the hypothesis passing empirical and theoretical tests is less false than all the alternatives considered. This gap between the best procedures humans have come up with for weighing evidence and the unachievable procedures that a truth standard requires (e.g., testing all possible alternative hypotheses) gives more reason for thinking past objectivism and relativism. Nostalgia for the possibility of certain foundations for our knowledge claims can more easily be left behind us as part of the safety net we no longer need in order to make the best judgements we can about nature and social relations. Who needs truth in science? Only those who are still wedded to the neutrality ideal." (Harding, 1994, p.100)



Thus renouncing the chimera of neutrality also means relinquishing the idyllic notion of science as the pursuit of truth. However, abandoning neutrality does not mean giving up the ideal of objectivity. When values are brought into play in shaping science, objectivity does not suddenly evaporate - only objectivism is knocked out. In shaping science with Islamic values, we are openly acknowledging the roles that values play in science. This is why in Explorations in Islamic Science (Sardar, 1989), Islamic science was described as 'subjectively objective'; Sandra Harding (1994), more appropriately, calls the same process 'strong objectivity' - that is, an objectivity that honestly declares its values and subjective elements up front. From the alleged neutrality and objectivism of science, we thus have to move forward towards strong objectivity.

Strong objectivity is the basis on which we need to develop models of Islamic science policies and science education curricula. Using the matrix of the fundamental concepts of Islam, Islamic science policies have to be developed both at the level of Muslim countries as well as the transnational level of Muslim community: the ummah. The problems and potentials of Muslim countries are complex and varied; not all Muslim countries have the potential to solve many, or indeed any, of their problems within the limits of their own resources. But collectively, the Muslim world possess enough resources to solve most of its problems. Thus national weaknesses in scientific research have to be tackled at regional levels by joint research endeavours. At present, most Muslim countries either have no science policy at all or have policies that make science subservient to economic or military policy or give some notional lip service to science in national development plans. We therefore need to develop mechanisms by which Islamic science, as is dictated by the notion of ilm (knowledge), is moved to the centre of Muslim cultural, social and economic life. In other words, Islamic science, as pursuit of objective knowledge and as ibadah, occupies the same place in Muslim everyday concerns as prayer, fasting and other forms of worship. However, given the current status of Muslim societies this is a tall order.

If the discourse of Islamic science is to move from the pages of scholarly books and journals into the real world, it must receive serious support from Muslim states. Conventionally, it has been argued, that a country must spend at least one per cent of its gross national product on science to give science its due. But most Muslim countries have not even managed that. However, as the newly industrialised states of south-east Asia have shown, those who are really serious about science, and hence viable development, have to devote far greater amounts to science. Malaysia, for example, has poured as much as ten per cent of its GNP in science and education: the results can be seen in the level of its achievements from almost 100 per cent literacy to its scientific infrastructure to its high-technology manufacturing base. Transforming Muslim societies to knowledge-based societies requires an even greater level of commitment. A science policy that is justified with the adjective 'Islamic', or a state that claims to be an 'Islamic state', must be committed totally to the endeavour of knowledge generation. Islam and ignorance are antonyms: even though the two seem to be close associates in contemporary times!

However, the development of Islamic science policies cannot be left only to states: administrative services, experts, ministries and faceless bureaucracies. It has to reflect both istislah, that is public interest, as well as public participation. Thus any science policy that is worthy of the label 'Islamic' must actively involve the citizens in its formation. The participation of the citizens in decisions of science policy assumes an awareness and well informed public which itself requires the transformation of scientific activities into social institutions. Here, the recognition by the state that science plays an important part not just in the modern world, but also in creating an informed, tolerant, socially aware and enlightened Islamic society, has to be the first and necessary step. But individuals and communities themselves cannot be passive on this issue: scientific ilm has a direct bearing on our individual and communal lives and it is an obligation that we have to meet, whatever the sacrifices. We thus need to discover how we can

redirect the religious energies of our communities, which are currently being used largely for destructive purposes, towards creating ilm-based societies.

Both at the national level and the level of ummah (global Muslim community), Islamic science policies have to identify specific areas for target research - research geared to solving the most pressing and urgent problems of our societies - and the place with the best potential for conducting this research. Thus at a national level, major material, health, environmental and social problems must all have designated research centres devoted to target orientated research. Here, both public as well as private sectors must play an equal role in financing and promoting research and development activities. In each area of public concern, careful choices of institutions, fields and foci have to be made. Similarly, we need to identify areas of research at the level of the ummah which reflect its current problems and needs. Consider, for example, that almost three-quarters of all the political refugees in the world are Muslims. There ought to be a centre of excellence somewhere in the Muslim world devoted exclusively to the problems of refugees: developing materials for quick and clean temporary housing, efficient and cheap methods for supplying emergency water, mechanisms for providing basic health care and preventing the spread of diseases and other systems for reducing the hardship and relieving the misery of the helpless and innocent victims of political turmoil. Certain essential areas of research which would be too much of a burden on for individual Muslim countries, for example advance computer systems or molecular biology, need to be promoted at the level of the Muslim world. Here, we need to identify areas of research that could become crucial for the survival of Muslim societies in the future as well as develop mechanisms for joint finance and management of a string of international centres of excellence located in the major centres of the Muslim world. Some thought to developing long-term linkages between scientific and research institutions within the Muslim world is also essential. Some Muslim countries like Malaysia, Turkey and Egypt have reasonably well developed scientific infrastructures: their experience in knowledge production needs to be

passed on to other Muslim states and contacts and linkages have to be established so that resources can be pooled and common problems tackled more effectively.

Science that is actively shaped and directed by an open set of values, will, of course, be resisted by the puritan strand of Muslim scientists arguing that 'pure' and 'fundamental' research cannot be interfered with. This research has to be done for its own sake. However, we have to vigorously resist any notion that scientists and researchers are helpless to make choices among envisionable future lines of research and development, or they are totally dependent on the science of the industrialised countries. Whatever view we may hold of research already undertaken, it is wrong to think that not-yet-accomplished research, which cannot be undertaken without commitment of will and resources, is anything other than value-laden. And, given the complexity of scientific work and the rate of contemporary changes, it would be simple-minded not to recognise that at the moment of its emergence new knowledge could have beneficent as well as maleficent potential that demands our constant attention: 'questions of practical ethics always lie in what to do next'.

In our attempts to rediscover <sup>a science set in the cultural context of Islam</sup> we have to allow ample space for the growth and development of traditional knowledge. Muslim countries have a valuable, although largely, untapped reservoir of indigenous knowledge and experience on medicine, agriculture and natural resources. Islamic medicine, for example, is a highly sophisticated system of medicine and health care that led the world for some eight centuries. There is a very good reason why it appears a little outmoded: during the colonial period, it was systematically suppressed, outlawed and marginalised so that Western medicine could take its place. Originally, Islamic medicine was a system that progressed by continuous research. However, both due to the decline of Muslim civilisation and the fact that research on and teaching of Islamic medicine was prohibited by colonial powers, its development ceased around the middle of the eighteenth century. So what

we have is a system that reflects the contents of the medicine of that period. However, if research on Islamic medicine was appropriately promoted, it would develop and bloom into a fully-fledged alternative system of medicine that could easily be better than the system of modern, western medicine. Similarly, traditional agricultural and water management systems have proved to be highly effective and ecologically sound. For example, the traditional 'chain wells', known as karez in Persian and qanat in Arabic, have been shown to be superior to modern irrigation schemes (see Hillel, 1994). These ingenious systems consist of one or more mother wells drained through a network of tunnels. For centuries before the arrival of the tubewells, the ecologically sound and the exceptionally durable qanats served as the principal means for supplying water for irrigation to villages and towns. Research on indigenous knowledge has revealed that valuable traditional science is available in such fields as ecology, soil science, veterinary medicine, forestry, human health, aquatic resource management, botany, zoology, agronomy, agricultural economics, rural sociology, mathematics, fisheries, range management, information science, wildlife management and water resource management (see Warren et al, 1993). This knowledge is an important resource that we cannot overlook. It needs to be tapped, upgraded where necessary, made an important part of science policies of Muslim countries, integrated into the national system of science and used in designing development projects.

Undoubtedly one of the most formidable tasks that faces those who wish to shape science with Islamic values is the question of methodology. An obvious candidate for replacement is vivisection that has become the dominant methodology of modern biology. Our ethical concerns here lead to some tough questions: what happens to much of contemporary biological research if we are to shun torture of innocent animals in the name of progress? How can we ensure that research on such areas as cancer continues? What alternatives to vivisection can we develop? Similarly overwhelming questions arise when we argue for replacing perpetual, and often meaningless reduction, with synthesis. What methods would encourage synthesis and bring it

to the level of the laboratory? How can synthesis become the dominant paradigm of science? We need to tackle these questions seriously if we are to take the discourse of Islamic science beyond its present impasse.

Finally, there are fundamental axiomatic questions just waiting to be addressed. What happens to modern science if its basic metaphysical assumptions about nature, time, universe, logic and the nature of our humanity are replaced with those of the worldview of Islam? How do we actually perform the task? How will it transform physics and what would the new physics look like? What new disciplines will be generated? How will the new axioms change mathematics? What new directions about our understanding of the material universe and reality will be opened up? And, last but not least, what impact would this have on developments in science education?

It took modern, Western, science over three centuries, and all the resources of colonialism and neocolonialism, to reach its present level of complexity and sophistication. Discovering alternatives to and in modern science will thus not be a simple or easy exercise. It will require sustained and prolonged intellectual and financial commitment to even begin to highlight the contours of a viable Islamic alternative. To become meaningful and engage more seriously with the challenge, the discourse of Islamic science (or, more appropriately, science in the context of Islam) must lift itself from its current obsession with feel-good rhetoric and ontology. Only pragmatic policies, conscientious empirical labour and sober theoretical and methodological work, can move the Islamic science discourse forward - and lead, eventually, to a holistic and rigorous science education and humane future for the Muslim world.

The emphasis on moral and spiritual dimensions in the National Curriculum do, in my judgement, allow Muslim science teachers to develop such holistic perspectives for their pupils

in Muslim schools. Such developments, if actively pursued, could take on the function of a blueprint for science education curricula in various parts of the Muslim world. But how did these dimensions take shape and fuse together in the form of a National Curriculum for science? We need to review the antecedents to this curriculum to find out.

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## **CHAPTER 3**

### **THE ANTECEDENTS TO THE ENGLISH NATIONAL SCIENCE CURRICULUM**

- 3.1 Introduction
- 3.2 The Original National Curriculum
- 3.3 Views, Recommendations, and Policy Statements of The Association for Science Education
- 3.4 Views, Recommendations and Policy Statement of Her Majesty's Inspectorate and the Secretaries of State at the Department of Education and Science and for Wales
- 3.5 Some Views and Recommendations of the Secondary Science Curriculum Review
- 3.6 Views and Recommendations of the Royal Society
- 3.7 Views and Recommendations of the Science and Technology Working Party for the National Curriculum, DES, 1988
- 3.8 Summing Up

## THE ANTECEDENTS TO THE NATIONAL CURRICULUM

### 3.1 Introduction

In this chapter I review some of the important antecedents to the English National Science Curriculum with the aim of finding out whether any consensus emerged on their views about the nature of science. Although the documents were separately conceived and written, my intention is to pull out any common threads that may connect the perceptions of the thinkers and writers. Hence, the chapter is necessarily descriptive.

### 3.2 The Original National Curriculum

The Education Reform Act of 1988 provided for the establishment of a National Curriculum in England and Wales comprising core and other Foundation subjects, to be taught to all pupils of compulsory school age in maintained schools, for each of which there would be appropriate attainment targets, programmes of study and assessment arrangements.

In July 1987 the Secretaries of State for Education and Science and for Wales appointed a working group, under the chairmanship of Professor Jeff Thompson, Pro-Vice-Chancellor and Professor of Education at the University of Bath, to advise them on appropriate attainment targets and programmes of study for science. On the basis of the group's advice, proposals were made in accordance with the provisions laid down in the Education Reform Act. The final report by this delegated group on Science for ages 5 to 16 also made recommendations in relation to the functions of the National Curriculum Council (NCC) and the Curriculum Council

for Wales (CCW) and to the resources, staffing and teacher training implications of establishing science within the National Curriculum.

The following quotation from the foreword to this report is informative:

“The Act defines attainment targets as:  
the knowledge, skills and understanding which pupils of different abilities and maturities are expected to have by the end of each key stage’.

and programmes of study as:

the matters, skills and processes which are required to be taught to pupils of different abilities and maturities during each key stage’.

The four consecutive key stages are the years of compulsory schooling which end when pupils in a class are 7, 11, 14 and 16. The Act empowers the Secretaries of State to specify attainment targets and programmes of study. Before they may draft Orders, they are required to make formal proposals in accordance with the provisions of the Education Reform Act. In England, the Secretary of State for Education and Science is required to make proposals to the National Curriculum Council (NCC) which in turn is required to consult, and then to make a report to the Secretary of State, containing a summary of views expressed on his proposals and the NCC’s advice and recommendations. In Wales, the Secretary of State for Wales is required to give notice of his proposals to the Curriculum Council for Wales (CCW), and to any other persons with whom consultation appears to him to be desirable. In the light of the NCC’s advice and the outcome of the parallel consultations in Wales, the Secretaries of State proceed to draft Orders, allowing a minimum period of one month for further evidence and representations before the Orders are made.” (DES, 1988)

A National Curriculum for science had been in preparation for many years. In particular the DES published a ground-breaking document Science 5-16: a statement of policy (DES, 1985) which for the first time identified the framework for a centrally directed science curriculum. The document was built around a wide consensus. Thus, the National Curriculum in science has a number of very significant intellectual antecedents. It is necessary, therefore, to analyse the explicit statements and implicit assumptions concerning the nature of science education made by the following bodies:

The Association for Science Education (ASE)

The Royal Society (RS)

The Department of Education and Science (DES) and

Her Majesty's Inspectors (HMI)

The Secondary Science Curriculum Review (SSCR) - largely an ASE initiative involving teachers, not mandarins.

Such an analysis is a prerequisite before making a formal assessment as to what kind of philosophical framework underlies the National Curriculum, and what view of science education is embodied by it. The justification for the choice of organisations listed above comes from the National Curriculum Science and Technology Working Party itself (August 1988), which takes due account of the relevant work of the bodies listed above in the formulation of its final proposals. (It should be noted that the Working Party took as their policy framework the DES document entitled Science 5 - 16: A Statement of Policy.)

### 3.3 Views, Recommendations, and Policy Statements of The Association for Science Education.

#### Alternatives for Science Education: A Consultative Document (ASE, 1979)

This consultative document was prepared by a small Working Party established under the auspices of the Education (Research) Committee of the Association for Science Education. Its aim was “to present alternative courses of action that may be followed by those concerned with the place of science in education” (p.7).



One of the most significant and revelatory passages in this document speaks of the implicit values and assumptions underlying the teaching of science and, by extension, the nature of science itself. Thus:

“Science teachers have not, until quite recently, subscribed to explicit psychological or sociological models when devising teaching and learning schemes. Nevertheless, science teaching has always been based on a range of implicit values and assumptions concerning the psychological development of young people, the nature of learning, the nature of knowledge in general and scientific knowledge in particular” (p.21). (my emphasis)

The implicit values and assumptions have a definite bearing on the conceptual and methodological base of science education. One of the fundamental methodological assumptions of science teachers in general is to view scientific method as a monastic entity, internationally agreed and universally applicable. (Science teacher views about the nature of science are discussed in Chapter 8 - the interpretation of my fieldwork on a sample of Muslim and non-Muslim science teachers.) Speaking about methodology in science, the report claims that there is an:

“almost universally agreed and accepted formulation of scientific method as taught in schools; a method that is formal and consisting of set procedures that can be systematically applied to the resolution of any problem arising in the course of a normal and well planned lesson. The Kuhn-Popper debate does not appear to disturb the calm methodological seas of school science” (pp.23-24).

The document goes on to say that most science teachers, who are themselves products of a science education that places a high premium on scientific knowledge while paying lip service to the history and philosophy of science, share with many practising scientists a scant understanding of the nature of scientific knowledge itself. They visualise science as a body of knowledge with a centralised and specific methodology, and a set of values that have an autonomous existence, uninfluenced by the social world. The application and misapplication of ordinary human values in the selection of scientific problems, the resolution of methodological issues and the preparation and presentation of results, does not dawn upon them. The objectivity,

value neutrality, universality and international character of science is an assumption unchallenged in their training or practice.

“The popularizers and sceptics, such as Bronowski and Koestler, are dismissed almost out of hand, and the writings of Medawar and Jevons are regarded, if considered at all, as mild perturbations of the otherwise equable climate of scientific theory and practice” (p.24).

There is a distinct tendency, through accident or design, to dissociate the application or utilization of science from its knowledge content. There is no attempt to relate science to social, economic, political and environmental realities, thereby lending credence to the erroneous belief that science is more concerned with system maintenance than social purpose. School syllabuses reflected this bias by emphasising theoretical content at the expense of real personal involvement, so that the pupil comes to believe that the scientific findings he is presented with are the immutable intellectual products obtained through the application of a non-problematic methodology.

The rest of the argument is better quoted:

“A lack of opportunity to explore the history and philosophy of science and to study science in its social, economic and political contexts is perhaps a major contributory factor to the popular image of science gained by young people. What they see is a subject dominated by facts and principles established outside their experience of everyday life. They study a subject isolated from its history or context and which is also very demanding, time-consuming and complex. This image results in part from the failure to locate science studies in the everyday context of life and work, and in part from the failure to integrate science into the common culture. The majority of young people fail to demystify the subject and do not see science for what it is - one of the most important cultural activities devised by man” (p. 24).

In the Curriculum Proposals section of this document (Part Three, p.37 onwards), the contributors enunciate the following broad aims as being the most relevant in terms of school science education:

- (a) the acquisition and understanding of scientific knowledge, generalisations, principles and laws, gained through a systematic study and experience of aspects of the body of knowledge called science;
- (b) the acquisition of a range of cognitive and psychomotor skills and processes gained through the repeated involvement in scientific activities and procedures in the laboratory and the field;
- (c) the utilisation of scientific knowledge and processes in the pursuit of further knowledge and deeper understanding, leading to the ability to function autonomously in an area of science studies. This also involves the ability to communicate with others.

In broader curricular terms the achievement of the above aims enables the individual to:

- (d) gain a perspective, or “way of looking at the world” that complements and contrasts with other perspectives or methods of organising knowledge and inquiry, and without which the individual cannot achieve a balanced general education.

Science education is, and emphatically should be, an essential component of the general education of the individual. Its primary justification, and therefore purpose, is to foster and develop a scientific way of thinking, a basic knowledge of scientific ideas and an ability to communicate with others. It is understood, moreover, that the precise realisation of this purpose depends essentially on the way science is defined in conceptual and methodological terms.

Interpersonal communication generated by practical science activities and fieldwork would provide opportunities for youngsters to gain a sense of social meaning and identity as well as personal autonomy. Given that western society is heavily dependent on scientific and technological knowledge and its utilisation, science studies that include the history and sociology of science provide opportunities for

**“explaining, and therefore understanding, the nature of advanced technological societies, the complex interaction between science and society, and the contribution science makes to our cultural heritage” (p.38).**

These aims, or purposes, of science education are deemed to be common for all pupils irrespective of social background and academic ability. They are socially oriented, designed to enhance the notion of science as a cultural and instrumental activity. They also meet Bullock’s assertion that

**“All I am sure of is that the more it is possible, legitimately, to move away from a monolithic, mechanistic, dehumanised image of science; to establish a view of it as a humane study, deeply concerned both with man and society; providing scope for imagination and compassion as well as observation and analysis; and calling, in those who succeed in it, for outstanding personal qualities, the easier it will be to overcome the sense of alienation which turns many young people away from it”. (Bullock, 1976)**

On pp.43-50, the ASE Working Party presents three possible models of a school science curriculum. The common intellectual foundation for all three curricular models is borne out by the following fundamental points which assume intellectual centrality, that

- the initial stimulus for activities is to be derived from the biophysical and social environment of the school and its community.
- actual phenomena, events and observations should act as “triggers” for hypothesis investigation rather than relying on “experiments”.
- optional studies should be available for the higher years of the school. One such option should be the History and Philosophy of Science which would:

**“provide a valuable bridge between science and the arts and social sciences, either as a course of study in its own right, or as a contextual course taken in conjunction with one of the empirically-oriented options” (p.44).**

Finally, this discussion document also appreciates the far-reaching implications that such a fundamental reappraisal of science education would bring about:

“In suggesting that in the long-term school science should move away from an incremental, and at times iterative, approach to content, and towards an overtly experiential and personal construction of scientific understanding, raises fundamental questions concerning the nature of educational processes, the purpose of educational institutions, and the relationship between the learner and what is learnt” (ASE, 1979, p.50).

### Education through Science: Policy Statement (ASE, 1981)

This document is a natural subsequence to the ideas incorporated in the Association policy statements published in the 1970s, viz: Science and General Education (1971), Science for the Under-Thirteens (1971) and Science for the 13 - 16 Age Group (1973). Further momentum was given to this project as a result of the national debate on the future of the educational system which was initiated in Mr. James Callaghan’s speech at Ruskin College, Oxford, in October 1976. The latter led to the publication in January 1980 of the DES consultative paper A Framework for the School Curriculum (1980), The School Curriculum (1981), the HMI paper A View of the Curriculum (1980) and Schools Council Working Paper 70, The Practical Curriculum (1981). Some of these documents shall be analysed in a subsequent section of this chapter.

### The Place of Science in the School Curriculum

The 1981 policy statement makes the following assertions.

1. Education through science is an important component of general education and as such should continue to be recognised as part of the core, or protected, element of the curriculum. Schools should therefore have a curriculum strategy that facilitates achievement of the Association’s aims for science education through appropriate work in other subject areas. The approach suggested is one based on the notion of science

across the curriculum, constructively penetrating discipline barriers.

2. All pupils should have the opportunity to benefit from a full and effective programme of science education throughout their period of compulsory schooling. This, of course, is a natural corollary to statement 1.
3. All schools should have a strategy that enables aspects of the aims for science education to be achieved through appropriate work in science and other subject areas. The Association is convinced that the aims of science education it presents, and the contexts within which science studies should be explored, are of central importance and can only be fully achieved through a coordinated and planned approach to the total curriculum.
4. All schools should develop an approach to science studies based on the notion of science across the curriculum which sees science as essential in the development of a common or core curriculum at the primary and secondary levels of schooling.
5. The science curriculum should incorporate a reasonable balance between the specialist and generalist aspects of education through science and should reflect the range of contexts and aims specified.

The document maintains that science, in its various forms, represents a way of organizing knowledge that contributes significantly to the cultural and intellectual development of society. Like any other discipline, science provides a means whereby the individual can organize his or her own concepts and attitudes, classify experience and communicate with others. Like history, fine art or craft, science requires the individual to come to terms with a particular approach to issues and problems.

Scientific knowledge and processes should also be deployed within a wider range of contexts. The Association is convinced that in planning and developing the science

curriculum, science should be explored from the viewpoint of the following contexts if it is to make an effective contribution to general education, prepare young people for their adult life in the community at large, and form a satisfactory base for post-school education in science, engineering and technology (pp.10-11).

- “(i) Science as an intellectual discipline: the pursuit of scientific knowledge as an end in itself which leads to an understanding of the essential principles and processes of science and allied disciplines.
- (ii) Science as a cultural activity: the more generalised pursuit of scientific knowledge and culture that takes account of the history, philosophy and social implications of scientific activities, and therefore leads to an understanding of the contribution science and technology make to society and the world of ideas.
- (iii) Science and its applications: the development of an appreciation and understanding of the ways in which science and technology contribute to the worlds of work, citizenship, leisure and survival. We would include under this heading an understanding of the way scientific and technological ideas are used to create and maintain an economic surplus, facilitate participation in democratic decision making in a technological society, enrich and sustain a wide range of leisure activities and pursuits, and enable the individual to utilize scientific ideas and technological processes in the context of increasing self-sufficiency, the conservation of resources and the utilisation of alternative technologies.”

6. Current provision at the primary and secondary levels suffers from a number of important weaknesses and the Association believes that a strong case exists for the further development of school science teaching.

### Role of the Teacher

The Association believes that the key role of the teacher of science is that of enabling each pupil to relate his or her own perception of scientific understanding to the wider community of scientific ideas. Whilst such a process involves moving the pupil closer to the ‘accepted truth’, all concerned should accept the absolute legitimacy of the ‘perceived truth’ - the right of the individual to interpret his or her own experience in his or her own language or words.

“Science, as an intellectual discipline, eschews dogma. The teaching of science must similarly be free of pedagogic dogma and notions of teacher infallibility. At the same time, the onus rests on the teacher to test the strength of pupil’s views by creating situations that utilize experiment, observation, and the literature of science in order to question the assumptions made. Difficult as this may be in practice, it is an ideal which should be worked for on the grounds that the testing of a hypothesis held by a pupil is far more valid in educational terms than any hypothesis presented on a worksheet, a blackboard or a computer terminal” (p.32).

### 3.4 Views, Recommendations and Policy Statements of Her Majesty’s Inspectorate and the Secretaries of State at the Department of Education and Science and for Wales.

#### A View of the Curriculum, (DES, 1980)

In Local authority arrangements for the school curriculum (DES, 1979), the Secretaries of State for Education and Science and for Wales announced that:

“they believe they should seek to give a lead in the process of reaching a national consensus on a desirable framework for the curriculum and consider the development of such a framework a priority for the education service.... As a first step towards the development of such a framework the Secretaries of State have invited HM Inspectorate to formulate a view of a possible curriculum on the basis of their knowledge of schools”. (DES, 1979, p.9)

This document is a response to that invitation.

In this document, the HMI have categorised the experience and understanding to be sought through the curriculum as:

aesthetic and creative

ethical

linguistic

mathematical

scientific



physical

social and political

spiritual

The scientific experience does not receive expansive treatment as the document is more concerned with adumbrating an overall curricular framework. In Proposition 8, the HMI contributors declare the following:

“In any future development of the curriculum, to those elements already widely held in common - English, Mathematics, Religious Education, Physical Education - should certainly be added some continued form of science education for all pupils. Whether or not it is presented under the traditional separate science subjects - and the individual school will have to decide on this in the light of its circumstances - it should be of a sufficiently broad kind to familiarise all pupils, at levels within their understanding, with important concepts and knowledge which may both stimulate their minds and their imagination and equip them better for their future responsibilities as citizens. School science is one of a group of subjects, including Mathematics and Craft, Design and Technology, which clearly have an important part to play in developing understanding and appreciation of Technology. Engagement with the processes of science should also be helping to strengthen general powers of observation and reasoning.”

#### The Curriculum from 5 to 16 (DES, 1986)

This paper is one in a series of discussion documents published by HM Inspectorate under the general title Curriculum Matters. It seeks to stimulate professional discussion about the whole curriculum, about the possible basis for agreement, about the broad purposes of primary and secondary education in England and Wales and about the ways in which teachers working in schools might give them expression.

The following documents - Education in schools (DES and Welsh Office) 1977, A framework for the school curriculum (1980) and The school curriculum (HMSO, 1981) proposed a number of educational aims for primary and secondary schools. They were:

- to help pupils to develop lively, enquiring minds, the ability to question and argue rationally and to apply themselves to tasks, and physical skills;
- to help pupils to acquire knowledge and skills relevant to adult life and employment in a fast changing world;
- to help pupils to use language and number effectively;
- to instil respect for religious and moral values, and tolerance of other races, religions and ways of life;
- to help pupils to understand the world in which they live, and the interdependence of individuals, groups and nations;
- to help pupils to appreciate human achievements and aspirations.

The HM Inspectorate claim that, in general, these aims command widespread support and are reflected in the aims drawn up by many local education authorities (LEAs) and individual schools. They apply throughout the years of schooling, to all types of school and across the whole range of ability. In the Inspectorate's opinion, whatever means a school uses to translate its aims into everyday curricular terms, and whatever means it uses to provide appropriately for pupils of different ages and abilities, broad aims of this sort should underlie its day-to-day work in respect of all its pupils.

By way of elaborating the stated educational aims, and facilitating their implementation, the following areas of learning and experience are categorised:

aesthetic and creative

human and social

linguistic and literary

mathematical

moral

physical  
scientific  
spiritual  
technological

It is emphasised that these are not discrete elements to be taught separately and in isolation from one another. Each area of learning and experience should make its unique contribution, assisting in the development of knowledge, concepts, skills and attitudes which can be learnt, practised and applied in many parts of the curriculum.

“The scientific area of learning and experience is concerned with increasing pupils’ knowledge and understanding of the natural world and the world as modified by human beings, and with developing skills and competencies associated with science as a process of inquiry” (p.29).

The Inspectorate maintain that these include observing, selecting from the observations whatever is important, framing hypotheses, devising and conducting experiments, communicating in oral and symbolic forms and applying the knowledge and understanding gained to new situations.

The first stage of this process is didactic. Pupils need to be taught to organise the data gathered through observation and investigation conducted by themselves and others. Prediction and explanation are the principles underlying the second stage. They should look for relationships and patterns and try to find explanations for them. Encouragement should be given towards seeking alternative explanations, to select those which seem most probable and to test them by experiments.

The process aspect of science education is heavily stressed. Observation and handling of objects should be encouraged, as well as participation in enquiries through which skills related

to science as a process can be developed. Making the most of opportunities of turning a question into a practical investigation should lie at the heart of science teaching and learning.

The appreciation of the need to repeat tests in order to ensure consistency of results, is also an important quality to develop within the repertoire of the pupils' skills. If inconsistency sets in, then the ability must be there to investigate the causes of such variation and to change the design of the experiment.

Concerning the cross-curricular excursions of scientific method, the contributors claim that

“scientific education involves a number of valuable processes which, although they are characteristic of the way in which the scientist works, can also be fostered in other subjects. Indeed, in the rational and logical consideration of any problem there are elements of scientific method. History and geography are only two of the subjects in which pupils should be expected to collect evidence, judge its relevance to the present purpose, identify significant features or patterns in it, offer explanations for them, test the explanation by reference to other evidence and arrive at a conclusion based on this process” (pp.31-32).

Scientific learning should help to improve communication skills, foster attributes such as open-mindedness, flair and originality, cooperation and perseverance. This in turn, it is believed, would produce citizens better informed about, and competent to judge, the impact of scientific developments upon individuals and society at large.

#### Science 5 - 16: A Statement of Policy (DES, 1985)

This was a ground-breaking document which for the first time identified the framework for a centrally directed science curriculum.

Right from the very outset in this DES policy document, the position of science education is centralised within the school curriculum. Thus:

“science should have a place in the education of all pupils of compulsory school age, whether or not they are likely to go on to follow a career in science or technology. All pupils should be properly introduced to science in the primary school, and all pupils should continue to study a broad science programme, well suited to their abilities and aptitudes, throughout the first five years of secondary education” (p.1).

Not only is science education centralised, but its approach is universalised as exemplified in the statement that

“each of us needs to be able to bring a scientific approach to bear on the practical, social, economic and political issues of modern life” (pp.2-3).

It is claimed by the writer of the policy document that an introduction to the scientific method (note the singular) contributes to the preparation of children and young people for adult and working life as well as to their intellectual development. Observation, measurement, communication, prediction, explanation and appreciation of the relationship between cause and effect, provide the requisite background for the solving of problems in an everyday context.

It is also recognised that science can and should foster a range of desirable personal qualities. These include the encouragement of curiosity and healthy scepticism, respect for the environment, the critical evaluation of evidence, an appreciation of a significant part of our cultural heritage and an insight into man’s place in the world which will complement the contributions of other elements in the school curriculum.

For the full development of scientific competence, the Secretaries of State suggest that the science courses provided should give pupils, at all stages, appropriate opportunities to:

- “• make observations;
- select observations relevant to their investigations for further study;
- seek and identify patterns and relate these to patterns perceived earlier;
- suggest and evaluate explanations of the patterns;
- design and carry out experiments, including appropriate forms of measurement, to test suggested explanations for the patterns of observations;
- communicate (verbally, mathematically and graphically) and interpret written and other material;
- handle equipment safely and effectively;
- use their knowledge in conducting investigations; and
- bring their knowledge to bear in attempting to solve technological problems” (pp.3-4).

### 3.5 Some Views and Recommendations of the Secondary Science Curriculum Review (SSCR)

#### Background to the SSCR

The Secondary Science Curriculum Review (SSCR) was set up in 1981 to bring about changes in science education in schools in England and Wales. It responded to the growing concern that science, while a major curriculum area, was not, in fact, meeting the needs of many young people and of society in general. The Review operated under the aegis of the School Curriculum Development Committee (SCDC) and is supported by the Association for Science Education (ASE). It has also been sponsored by the Department of Education and Science (as it then was) (and its Northern Ireland equivalent) and the Health Education Council. Although now defunct, its aims and objectives helped to crystallise the science education debate in the context of the National Curriculum.

- “1. To provide a broad common base of science education for students of all abilities, both sexes and all backgrounds. Additional material will be provided to meet the needs of individual young people with special needs.
2. To avoid early specialisation and keep open subject and career options for all students for as long as possible, thereby increasing educational opportunities.
3. To increase the amount of time spent on science by the majority of school students up to the age of 16. It is suggested that 11 to 13 year-olds spend ten percent of their time on science, 13 to 14 year-olds fifteen per cent, and 14 to 16 year-olds twenty per cent.
4. To replace the option of three sciences at GCSE level with a course which would lead to two GCSE passes in science. It is intended that double science will be an appropriate preparation for A level courses in separate sciences.
5. To encourage schools to redesign their science syllabuses taking into account the learners’ own needs and interests, the demands of advanced technology and the kinds of skills it requires, and the social and ethical implications of science.
6. To encourage science departments into a closer working relationship with other curriculum areas so that students may understand that science does not provide the only way of looking at the world and that the human condition may be explained from other perspectives.
7. To enable pupils to emerge from their science courses with sufficient confidence and information to deal with the applications of science in the adult world, and to continue to use and develop the skills they have learned.”

(ASE, 1987, p.44)

The Review has produced a number of Curriculum Guides in the Better Science series. Only two, however, will be selected for analysis of their science education statements as they are particularly relevant to the content of the thesis.

### Better Science: Making it Relevant to Young People (ASE for the SCDC, 1987)

Science education during the period of compulsory schooling needs to be characterised, to a significantly greater extent than is generally the case at present, by relevance and applicability. This is the central theme of this particular document.

Making science education relevant to young people means impinging on their thinking about themselves and their physical and social environment; focusing on objects and phenomena that are part of youngsters' everyday experience and which capture their interests; connecting with other aspects of their experience of secondary schooling, and with hobbies and leisure activities.

Relevance includes applicability, but is not equivalent to it. Pupils should have the opportunity to learn about the applicability of science (what it can be to them) as well as the applications of science (what it is used for by others). Both applicability and applications can be put into effect when learning to investigate phenomena and seeking to understand the world; when attempting to solve practical or technological problems; and when endeavouring to formulate views on some social and ethical issues that the practise of science poses to them as members of contemporary society.

The Review suggested that “adolescents may become increasingly disenchanted with school science because they have a dehumanised image of science and scientists, or because they have the impression that science is simply a collection of right answers that are arrived at by the correct application of somewhat impersonal, mechanical procedures” (p.4). The impression given to pupils, in analogical terms, is that a door which leads to the correct experimental solution has only one methodological key. School scientific investigations generally have predetermined answers, designed to illustrate previously taught theory rather than putting forward open-ended problems for scientific and technological solution.

The Review thus perceived problem-solving (by utilising the processes of science) as an important way of redressing the balance away from excessive emphasis on knowledge so that in science classes more attention is devoted to pupils doing science and relating science to out-of-



school contexts as well as to academic and laboratory contexts. In this connection, one should refer to the work of the Assessment of Performance Unit (APU) (now disbanded), who referred to science as problem-solving and conceived of the process of performing an investigation as a problem-solving chain.

It is stressed by the Review, however, that the problem-solving approach should not be confused or associated with the Nuffield-style idea of ‘discovery learning’. According to the latter, pupils are expected to ‘discover’ currently accepted scientific ideas through observation and experimentation. In other words, an experiment, by teacher or pupil, is perceived to have ‘worked’ only if it gives the ‘right answer’. The problem however is, that even if it does, there is no guarantee that pupils will infer the correct explanation. Indeed, the very assumption that they should be able to infer scientific principles from observations would seem to indicate a view of how scientists work that is naively inductivist. Such an approach is neither consistent with classroom realities nor soundly based.

The Review is also concerned to enrich youngsters’ experience of school science by making more use of the interconnections of science with human issues and everyday realities. It is endeavouring to contextualise school science by which they mean “the interweaving and integrating of theoretical principles, laboratory work and soon, with human contexts and issues” (p.16). To this end, it offers some fairly loose definitions of the various sorts of human contexts and issues to which school science can relate. These are reproduced below:-

#### SSCR: A Taxonomy of Contexts for School Science (p.16)

##### School Science in Context

Type of context. Studying science in relation to....

<b>The individual person</b>	oneself; one's personal ideas, beliefs, opinions, values, interests and aspirations; understanding oneself; one's personal wellbeing (health);
<b>Social and cultural</b>	domestic, family and community life; leisure and recreational activities; health issues, medical and social services; citizenship and politics; religious and metaphysical beliefs and values; ethics;
<b>Historical</b>	the historical development of scientific ideas and applications, and their social and cultural interactions;
<b>Environmental</b>	understanding the natural world about us; interactions of science and technology with the environment (local, national and global);
<b>Industrial, commercial</b>	processes and artefacts produced and economic by technological and engineering activity (see Section 5); industrial and agricultural production; the workings of industry; the consumption of goods and services; employment.

It should be borne in mind that youngsters may see a context as relevant because it links with some aspect of their developing ideas, beliefs, values ideals and interests. In this connection, the Review makes reference to the SATIS (Science and Technology in Society) project initiated by the ASE in 1984, as an impressive way of contextualising science to social, economic and technological applications and issues. One of the fundamental objectives here is to make students realise the difference between facts and opinions, that it is possible to have differing opinions and that there is not necessarily a 'right' answer. For it is the case, after all, that real life decisions usually involve compromise, imperfection and no single right answer, and goes beyond science.

With their aims in perspective (p.6), the Review discusses the multicultural implications of the content of the science curriculum. It asserts that specific issues of content with clear multicultural implications are largely restricted to biology. For example, difficulties can arise with Darwin's theory of evolution when it introduces the ideas of 'natural selection' and 'survival of the fittest'. When applied to human evolution, these ideas portray a linear sequence from ape, stone-age man, hunter-gatherer to modern-technological man. The process can all too easily be seen as one of progress in which the finality of evolution is identified with the economically successful white man. The inference of a hierarchy of races could be a logical subsequence for this type of thought. It is therefore important to stress that in actuality we are very ignorant about the origins of different racial groups and there is no evidence to suggest that any racial group has evolved further than any other (p.7).

The Review is also critical of the absence of a historical and cultural context to science education. It notes that although secondary school physics may mention the names of early Greek, Islamic or European scientists in passing, very little is ever made of the contexts in which they worked. In any case, an overwhelming impression is imparted that science is a Western enterprise - conceived, developed and successfully applied by their nationals. Students can thus emerge from schools with negative images of the science of non-Western societies. In order to dispel these images, the SSCR suggests that some history of science should be included in school science courses and, moreover, restricted studies should include the placing of European science in a world perspective and occasional biographical studies which should include those of scientists from a variety of cultures. (This was later to be taken up by the ASE in their work on developing multicultural and anti-racist dimensions to science teaching - see ASE, 1991.)

The impression of science as an enterprise conceived and perfected by a globally dominant Western civilization is related to the notion of omnipotent science. This negative notion, however,

has less credibility now than it used to. The document pointedly states:

“Now with the growth of the environmental lobby in this country, people are much more sceptical about the ability of science to improve the quality of their lives. Alternatives to the expansion associated with scientific materialism include the religious and conservationist stances. In a multicultural society both these orientations provide material to illustrate this aim. For example, in the debate over research on human embryos the established Churches have failed to produce a unified view, and we have witnessed interactions between moral and scientific perceptions. For other groups in our society the religious perspective may be much more clear. For instance Islam opposes all experiments with human embryos. Indeed, in order to provide guidance to their scientists, early Islamic philosophers attempted to classify sciences as either ‘praiseworthy’ or ‘blameworthy’.” (ASE for the SCDC, 1987, p.18)

Admittedly, most teachers lack the understanding of the reasons for many religious convictions. The Review expresses the hope, however, that when practical issues arise which highlight the differences between religious and scientific perspectives, the teachers concerned should respect the right of students to hold their views.

Special reference is made in this document to the contribution of the Leicester SSCR group whose ideas and policy statements are expressed in Science Education for a Multicultural Society (Leicestershire Education Authority, 1986). Their view of science and philosophical base underlying their multicultural science policy, is neatly outlined in the following passage:

“Science is, after all, an activity of human beings, acting and interacting. In fact, it is a social activity. Scientific endeavour, including the development of technology, is determined by the cultural, religious, environmental, political and economic factors, and it is an activity in which the entire human race has been and is involved.” (LEA, 1986, p.27)

From this philosophical perspective and conceptual framework, the Leicestershire Review group concerned itself with attempting to remove, from science teaching, the white ethnocentric view of scientific developments, and demonstrating how science can be used and misused in teaching about race. To fulfil this aim they list and suggest four curricular strategies:

- using science topics to consider the multicultural history of science;
- making reference to contemporary practice in other societies;
- drawing on the experience which some youngsters from ethnic minorities may have had personally or know about through their parents;
- using topics particularly from the biological sciences to counter so-call 'scientific' racism.

With this perspective, the Leicestershire group produced their own science department policy for multicultural education in science. Its aims and policy are very significant to the present discussion and make interesting reading.

Very astutely, the Review group gives a very important word of caution. The main purpose of the SSCR material is to show cultural diversity in the applications of science so that students begin to value other cultures. The inherent changes in all this, however, is that the material could be used for reinforcing prejudice rather than challenging it. Work on food preservation, for example, might be unfavourably compared to Western industrially packaged foods, or work on energy utilisation compared with the nuclear and military potential of the Western world. A wider social and economic context is therefore required, if the Eastern alternative is not to be assumed to have little value and, therefore, 'less advanced'.

The assumptions of the science teacher when presenting science are hence of crucial significance. The document rightly asks:

"Do we for instance promote the notion that 'progress is a good thing' or 'prosperity relies on sophisticated, scientific developments' or do we also consider with students the negative consequences of increased technological sophistication? We would argue that without open exploration of both the benefits and the negative consequences of different technologies, as well as the appropriateness of their use in particular circumstances, then no matter how much cultural diversity is introduced into our science lessons, students may still place

less value on practices which appear to them to be less ‘sophisticated’. It thus behoves us to encourage discussion of values in science lessons” (p.15).

These statements are quite significant in the present context, suggesting that school science topics having social and cultural implications can be discussed within a value framework. The latter could be based upon a variety of ideological, secular or religious systems, including that of Islam. (The Appendix to the thesis describes how a framework for such input was developed by the present author based on the former Attainment Target 17, The Nature of Science.)

### 3.6 Views and Recommendations of the Royal Society (The Royal Society, 1982)

The Royal Society Study Group had instrumental aims and objectives in their report to the Council of the Royal Society, rather than analysing the implications of science teaching in a multicultural society and putting forward policy proposals and recommendations. This is apparent from their terms of reference which were:

- “(a) To review the teaching and examination of science (including mathematics) in secondary (11-18) schools in England and Wales, with particular reference to the constraints imposed by
  - (i) the ability and motivation of pupils;
  - (ii) available manpower and financial resources;
  - (iii) the perceived needs of those academic, industrial and administrative institutions which recruit from secondary school.
- (b) To consider the needs of potential employers of trained manpower particularly in the following categories:
  - (i) those leaving school for immediate employment in technical posts;
  - (ii) those leaving school at 18+ for higher education whether in science or the humanities, who would later have the task of maintaining the country’s teaching, research and development capacity and participating in decisions affecting the use and management of scientists and technologists.
- (c) To consider how best to ensure an adequate national supply of manpower suitably trained for these tasks.

- (d) To make recommendations.” (Annex to the Report)

The general approach of the Study Group, in accordance with the terms of reference from the Council of the Royal Society as outlined above, was to try to understand and describe the main constraints on science education and the pressures which bear on schools from the demands of various groups and interests. In the early pages of this document, however, some significant statements about the nature of science are made to which we should turn our attention.

The Study Group admits that any discussion of science education presupposes a general common understanding of the main concepts involved and the terminology used to handle them, and that this in itself is an area of some difficulty, for there is no simple and universally accepted view of what science is or what the aims of science education should be. Moreover, “it is not possible to claim complete neutrality and objectivity in dealing with matters of this depth and we accept the necessity of setting out certain observations to reveal, as far as we can, the nature of the assumptions which we use and some definition of the terminology in which they are expressed” (p.3).

### Significant statements about the nature of science

The Study Group has made the following noteworthy statements:

- “0.10 The word science is used in many different ways, and the first need is to distinguish between them and find an appropriate nomenclature. It is easiest to begin with the familiar notion that science is knowledge and understanding of the natural world, characterised by its objectivity, in that it is derived from observations and experiments, and the hypotheses suggested and tested by them which do not depend on the individual making them. Moreover, science has substance, for it is about real and specific things and the facts of their properties and relationships, and it also has structure in that we can distinguish within it branches which have a certain autonomy in spite of their strong

interconnection. This structure is usually described by the familiar division into Physics, Chemistry, Biology and so on, but there is nothing absolute about this, for science and our perception of its structure unfold and develop with time and are never perfect or complete.

- 0.11 Scientific knowledge is gained in many different ways, Some are highly complex and sophisticated, others like observing, describing, counting, measure, tabulating and classifying are skills of which there are many examples in everyday life. The same can be said of scientific procedures such as generalizing, formulating and testing hypotheses and predictions, with all the demand on the imagination which this entails. There is therefore nothing mysterious about the ‘scientific method’ or about science itself. Science, however, does have a further fundamental attribute: like any other knowledge, it can be used, and in a very powerful way, not only to help our understanding of natural phenomena, but also to control and exploit them. In other words, science can be applied; and the applicability of science and specific examples of its application must be taught right from the beginning as an intrinsic aspect of science itself and not as a collection of topics to be tacked on as an afterthought.
- 0.12 It is useful and customary to use the word science to include not only scientific knowledge, but also and to an equal degree the activity of gaining this knowledge, extending it and using it, and to apply the term scientist to any person who spends a substantial part of his time engaged in these activities. He may also be called a technologist or an engineer if the main emphasis of his work is in application, but these terminological distinctions are not always necessary or useful, and too often obscure the combination of theory and practice which is at the heart of the matter. Real differences relate more to motivation. These can be considerable between the extremes of the “pure” scientist seeking to find out truths about nature and the engineer designing and making things useful to society. But the roots of motivation in an individual can change, sometimes in response to rapid changes of circumstance, sometimes through the more gradual development of a scientific career over a working life time.
- 0.13 Finally, science is a dominant feature of our civilization. It not only provides intense intellectual satisfaction and pleasure, at many different levels of difficulty, and fulfils a basic human need to know and understand, but it pervades our whole intellectual and material environment and everything we think or do. There can be no need for further justification of its place in the school curriculum.”

In accordance with these philosophical perspectives and educational deliberations, the report recommended that all pupils should follow a ‘science for all’ policy between ages 11 and



16, avoiding irreversible and limiting subject choices at an early age and the specialisation that goes with such option systems. The report described the sort of science curriculum that it envisaged. All pupils up to age 16 should study science for 20% of curriculum time (in the 4th and 5th forms - now Years 10 and 11 respectively), which embraces the three traditional branches (physics, chemistry, biology) and other sciences such as the Earth Sciences and interdisciplinary aspects. The curriculum should be taught in a more coordinated manner than is now generally the case, so that the relations between the branches of science, and between science and mathematics, become apparent. The science curriculum should include the teaching of content (knowledge, scientific methodology and applications of science) and the encouragement of the acquisition of the appropriate skills and approaches. It should offer practical opportunities to pupils in the sense of being 'relevant' to their needs, as well as including the appropriate experimental aspects. This model is termed a 'coordinated' science curriculum.

In fact a full working paper for such a curriculum was prepared by the Royal Society's Education Committee and presented to the Council of the Royal Society in December 1986. It was entitled: A proposal of reduced content for a coordinated science curriculum to age 16.

It is worthy of note that the Society's approach as described above is consistent with the growing consensus, notably among those in educational establishments, the Department of Education and Science (DES), Her Majesty's Inspectorate (HMI) and the Association for Science Education (ASE), that a more balanced science curriculum is needed and that a prerequisite for this is a reduction in content in secondary science courses. DES policy set out in Science 5-16: a statement of policy (HMSO 1985) referred to earlier, reflects this consensus.

3.7 Views and Recommendations of the Science and Technology Working Party for the National Curriculum (DES, 1988)

Background to the Working Group Proposals

The Working Group was asked in July 1987 to produce a report which recommended attainment targets and programmes of study for science within the framework of a national curriculum for pupils of a compulsory school age in England and Wales. The Group defined attainment targets as

‘clear objectives for the knowledge, skills, understanding and aptitudes which pupils of different abilities and maturity should be expected to have acquired at or near certain ages’

and programmes of study as

‘describing the essential content which needs to be covered to enable pupils to reach or surpass the attainment targets’. (DES, 1988)

In accordance with the request by the Secretary of State, the Group took as their policy framework, Science 5-16: A statement of policy (DES, 1985). Account was also taken of the relevant work of the Association for Science Education, in particular the policy statement Education through Science, and of the Secondary Science Curriculum Review’s guide, Better Science, of the General Certificate of Secondary Education National Criteria for the Sciences: Double Award, and, of course, the Royal Society recommendations. The proposals of the Group were eventually published in the National Curriculum document Science for ages 5-16: Proposals of the Secretary of State for Wales (DES/WO, August 1988).

## Views on Science and some Curricular Recommendations

“Science is a human endeavour and in its current study we need to acknowledge its history and future. It is a continuous process by which individuals and groups develop an understanding of the physical and biological aspects of the world. It is a way in which reliable knowledge about the world is progressively established through the generation and testing of ideas and theories. Faced with a new phenomenon, the scientist uses existing ideas which may then be modified or rejected if they do not help to explain it. The results of this scientific endeavour are progressively more powerful ways of understanding the physical and biological world” (p.6).

In this passage, the Group has made a statement of what they believe to be the nature of science and the distinct characteristics which underlie it. As far as the school curriculum is concerned they believe that science has an essential contribution to make in the following ways:

- (i) Understanding scientific ideas, so that pupils can use key concepts in unfamiliar situations.
- (ii) Developing scientific methods of investigation, such as systematic observation, making and testing hypotheses, designing and carrying out experiments competently and safely, drawing inferences from evidence, forming and communicating conclusions in an appropriate form and applying them to new situations.
- (iii) Relating science to other areas of knowledge, in order to gain knowledge, skills and inspiration from other activities.
- (iv) Understanding the contribution science makes to society, including exploration of the moral dilemmas that scientific discoveries and technological developments can cause.
- (v) Recognising the contribution science education makes to personal development, by developing attitudes such as tolerance towards uncertainty, cooperation with others, honest reporting and critical thinking.
- (vi) Appreciating the nature of scientific knowledge, by exploring the social and historical contexts of scientific discoveries and technological achievements.

The Group strongly recommends that attention needs to be given to the fostering of the following attitudes within the framework of science education, although they would not be assessed formally:

- curiosity
- respect for evidence
- willingness to tolerate uncertainty
- critical reflection
- perseverance
- creativity and inventiveness
- open-mindedness
- sensitivity to the living and non-living environment
- cooperation with others.

An attempt was made to foster these attitudes by implementation of the proposed 22 attainment targets (for ages 11-16) set within the four Profile Components of Knowledge and Understanding, Exploration and Investigation, Communication and Science in Action (DES, 1985, pp.18-71).

The last component - Science in Action - appears to be more innovatory than the other three. It sought to provide contexts and settings which can add additional meaning and purpose to the acquisition of knowledge and understanding. The attainment targets within this Profile Component made it a requirement to know about the nature of science, its limitations and changes with times and cultures. Thus:

“We see it as important that pupils living in a period of rapid change come to understand that science is a developing human activity, that its explanations and theories are usually useful in their time but essentially provisional in nature. Through their explorations and investigations, for example, pupils should gain

some experience of the power and limitations of scientific enquiry. In a similar way we see pupils, in the normal course of their work, relating their studies to social, economic and environmental issues” (p.66).

The view that the nature of science may vary from culture to culture is also expressed throughout page 92 of the Group’s proposals. Of notable merit is the view that, provided the teacher is open-minded, culturally diverse contexts/approaches to diet, nutrition, energy, health and the ecosystem could help to enrich the quality of science education for all pupils. A worrying piece of terminology, however, appears in the last sentence of paragraph 7.16 (p.92) which tends to contradict the more liberal statements made earlier.

“More generally, the science curriculum must provide opportunities to help all pupils recognise that no one culture has a monopoly of scientific achievement - for example, through discussion of the origins and growth of chemistry from ancient Egypt and Greece to Islamic, Byzantine and European cultures, and parallel developments in China and India. It is important, therefore, that science books and other learning materials should include examples of people from ethnic minority groups working alongside others and achieving success in scientific work. Pupils should come to realise that the international currency of Science is an important force for overcoming racial prejudice.”

‘International currency’ implies the existence of an international academic norm amongst scientists the world over. The ‘currency’ with which science operates would surely be different for civilizations operating within different conceptual frameworks and different methodological and metaphysical assumptions. The procedural currency of science is, of course, shared across cultures as scientists from different parts of the world are able to collaborate in major international projects, e.g. the Human Genome Project or nuclear fusion research. If science is perceived as having a powerful social, historical, and cultural context then the currency of science would be culturally biased. Overcoming racial prejudice then becomes a matter of attempting to understand one another’s cultural contexts in which science operates as opposed to coming to such a humane understanding through simply sharing the narrow procedures of science. This point was broached in Chapter 2.

### 3.8 Summing Up

In the documents reviewed there appears to be a distinct thrust towards adopting a contextual position to science and science teaching. An evolutionary pattern of contextualisation appears to be emerging, with recurring ideas and principles that relate to values in science education. The ASE, for example, has consistently recommended formalising this contextualised approach by encouraging due consideration of psychological and sociological models when devising teaching and learning schemes. Science is a cultural activity having a social, economic and political context as well as ethical implications.

All the documents reviewed in this chapter seek to develop a science curriculum that humanises science (by integrating theoretical principles and practical activities with human contexts and issues) and allows greater accessibility to pursue cross-curricular themes cutting across subject boundaries. How to teach science to a multicultural clientele (most of Britain's classrooms) is a theme that has been the subject of serious research by some of these science organisations (the ASE in particular) in recent years. Such studies are based on developments in the history, philosophy, sociology and anthropology of science spanning over the past three to four decades (see Chapter 2). As Sue Lyle's and Alyson Jenkins' introduction to their chapter on 'Making Global Connections Through Science and Science Teaching' (ASE, 1991) says:

"The social and political climate in which western science operates powerfully influences what research is done by determining what is valued and what is not. This also influences the ways in which science is applied, by politicians and industry, often to the detriment of the environment and people... It is important that teachers find ways of exploring moral and ethical dilemmas that scientific discoveries and technological developments can cause." (ASE, 1991)

So emphasis on a balanced science curriculum (the Royal Society), and raising awareness amongst teachers (and pupils) of nature of science issues (contextualised science teaching and

learning, as proposed by the ASE) were the central inputs to the government's Working Party for National Curriculum science. The Working Party produced proposals (as this chapter to some extent shows) incorporating these recommendations. A non-contextualised arbitrary basis to much of science teaching would (it was hoped) be overtaken by a contextualised, culturally-aware form of teaching. Science teaching and learning ought to be underpinned not by implicit assumptions held by the teacher but by explicit themes based on models developed through *sound* educational research.

With these inputs and their subsequent national recognition, the nature of science theme rose to prominence within the science curriculum. I was unable to identify, however, any consensus emerging on the nature of science theme in secondary science education. The separate conceptions of the ASE, Royal Society and DES Working Party were not unified to produce a consensus document on the nature of science and science teaching. Undoubtedly, this was confusing for science teachers who were subsequently asked (in 1991) to implement Attainment Target 17 (The Nature of Science) in the context of 17 science attainment targets. The sporadic nature of the various contributions to the nature of science debate (as described in this chapter) led, in my judgement, to an unfocused and nebulous position on the nature of science, frequently resulting in the emotional disturbance of secondary science teachers who had not seriously contemplated their own nature of science profile. Muslim science teachers working in Muslim schools were no exception, floating in a sea of curriculum uncertainty. It appears that the uncertainties and confusion never disappeared - indeed, as the results of my fieldwork show science teachers (Muslims and non-Muslims alike) have no consistent philosophical positions on the nature of science (see Chapter 6). The National Curriculum, however, has undergone significant changes during the course of this research. We need, therefore, to direct our attention towards these changes and assess how they have affected the nature of science debate.

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## **CHAPTER 4**

### **THE NATURE OF SCIENCE AS EXPRESSED THROUGH THE EVOLVING BRITISH NATIONAL SCIENCE CURRICULUM**

- 4.1 The Nature of Attainment Target 17
- 4.2 Science and Technology in Society (SATIS) - the mainstream project for Key Stage 4 pupils
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- 4.4 The Science in a Social Context (SISCON) Project
- 4.5 Supplementary Science Materials in the Context of Attainment Target 17
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- 4.7 Introducing and Analysing the Attainment Targets
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- 4.11 Implications for Muslim Schools Teaching Science

## THE NATURE OF SCIENCE AS EXPRESSED THROUGH THE EVOLVING NATIONAL CURRICULUM

### 4.1 The Nature of Attainment Target 17

The DES statutory document Science in the National Curriculum (HMSO, 1989), in its preamble to attainment target 17 (the nature of science), makes a non-transcendental statement about the nature of scientific ideas, locating their evolution within a social and cultural context. The moral and spiritual context to scientific ideas is also mentioned along with the recognition that science is one amongst many ways of thinking about experience.

“Pupils should develop their knowledge and understanding of the ways in which scientific ideas change through time and how the nature of these ideas and the uses to which they are put are affected by the social, moral, spiritual and cultural contexts in which they are developed; in doing so, they should begin to recognise that while science is an important way of thinking about experience, it is not the only way.”

The Working Party who produced the document gave due recognition to the methodological limitations of science and appreciation of the fact that scientific ideas develop within a social-cultural matrix and metaphysical framework. This understanding was to be conveyed, at the appropriate conceptual level, to pupils of all secondary state schools.

In the following table, the statements of attainment for target 17 are reproduced with a commentary alongside to bring out implicit assumptions and implications. These relate to the general idea that the statements of attainment are intended to convey and remark on the use of certain words and phrases which are not altogether clear, and may mask some underlying philosophical beliefs and/or assumptions. The former Attainment Target 17 is of central importance to the objectives of this thesis because it is concerned with the nature of science and the contexts in which it operates. It has therefore been singled out for special attention and commentary. (In section 6 of this chapter I discuss the impoverishment of the science curriculum as a result of jettisoning this attainment target along with spiritual and moral contexts to scientific discovery, retaining only the social and historical. This has destructive consequences for science education - see, for example, John Bausor, 1996).

**Table 4.1: Commentary on the 10 original level statements of Attainment Target 17  
(The Nature of Science)**

<u>Level</u>	<u>Statements of Attainment</u>	<u>Commentary</u>
Pupils should:		
4	- be able to give an account of some scientific advance, for example, in the context of medicine, agriculture, industry or engineering, describing the new ideas and investigation or invention and the life and times of the principal scientist involved.	- Provides scope for the development of supplementary educational materials to show how some important scientific ideas are viewed and have been viewed in different civilizations. Taking Islamic civilization, such an exercise has been attempted and presented as an integral component of this thesis.
5	- be able to discuss clearly with others their way of thinking about some experiment which is new to them.  - be able to demonstrate that different interpretations of the experimental evidence that they have collected are possible.	- The view of those who compiled the statements is that pupils' knowledge and understanding of the nature of science will originate from their own science activities. The use of the word 'new' is not very clear in this statement of attainment. It could, for example, refer to a laboratory context where a new investigation is encountered by a pupil hitherto unmet. The data accumulated would be second hand data designed to fit neatly in with previously taught theory and the conceptual category of a textbook. Or it could quite easily refer to an open-ended experiment which has no fixed procedure and whose investigational

<u>Level</u>	<u>Statements of Attainment</u>	<u>Commentary</u>
		<p>outcomes are unknown to both teacher and pupil.</p> <p>Social and cultural influences are omitted here. For some pupils, the nature of science may well be based upon their cultural and religious perceptions. It is an understanding of the processes of science which may originate from laboratory activities. Also, the teaching needs to be sufficiently open-ended to permit the collection of different interpretations leading to hypothesis formation and the design of further investigations.</p>
6	<ul style="list-style-type: none"> <li>- be able to use one or two explanatory models from their own learning in science to demonstrate how predictions have been made which stimulate new experiments.</li> <li>- be able to describe and explain one incident from the history of science where successful predictions were made to establish a new model, for example, the work of scientists on: <ul style="list-style-type: none"> <li>- airborne organisms (Pasteur)</li> <li>- the evidence for atmospheric pressure (Pascal).</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>- The aim here is to instil the skills of hypothesis formation and experimental design.</li> </ul> <p>The work of European scientists is naturally well known and extensively quoted. A global perspective, however, is educationally the most productive. A holistic position on science would encourage a sympathetic approach to scientific practice across different cultures.</p>

<u>Level</u>	<u>Statements of Attainment</u>	<u>Commentary</u>
7	<p>- be able to give an historical account of a change in accepted theory or explanation, and demonstrate an understanding of its effects on people's lives - physically, socially, spiritually and morally, for example, understanding the ecological balance and the greater concern for our environment; the observations of the motion of Jupiter's moons and Galileo's dispute with the Church.</p>	<p>- The social, spiritual and moral effect of a theory on people's lives should not be underestimated. Past clashes between proponents of a scientific theory and the religious establishment should not be presented in a way that endows the scientific enterprise with an illusion of value transcendency. It should be emphasised that there are other holistic systems in existence within the context of which some communities study and practise science.</p> <p>In other words, the power of a belief system and its value to society needs stressing, and that views held previously by the religious establishment and even the scientific community, although technically wrong, were not held because of intellectual stupidity. Role play exercises may serve to show that, relative to time and circumstance, views about the universe, man and society, can appear to be perfectly reasonable and therefore tenaciously held.</p>
	<p>- be able to demonstrate an appreciation of differing functions of scientific evidence and imagination in carrying</p>	

<u>Level</u>	<u>Statements of Attainment</u>	<u>Commentary</u>
	forward scientific understanding, for example, discovery of the structure of DNA - the different approach of Franklin from that of Watson and Crick.	
8	<ul style="list-style-type: none"> <li>- be able to explain how a scientific explanation from a different culture or a different time contributes to our present understanding.</li> <li>- understand the uses of evidence and the tentative nature of proof.</li> </ul>	<p>- This is best done through supplementary materials written by teachers from different cultural and religious backgrounds, placing original scientific explanations in their proper overall context. As mentioned before, this task has been attempted for the case of Islamic civilization.</p> <p>The scientific explanation would not be different for scientists from different cultures in terms of the nature of discovery and the jargon-laden language used to describe the investigational phenomena, followed by theoretical predictions and subsequent practical tests. The metaphysical framework or worldview of the scientist - the context in which he practices his science - would, however, be culturally dependent.</p>
9	<ul style="list-style-type: none"> <li>- be able to distinguish between generalisations and predictive theories and give an example of each, for example, such pairs might be: 'all metals</li> </ul>	<p>- The aim here is not to teach explicitly about the difference between 'generalisation', 'prediction' or 'model'. For this would be tantamount to teaching the philosophy of</p>

<u>Level</u>	<u>Statements of Attainment</u>	<u>Commentary</u>
	conduct electricity' and 'the theory of a free electron gas which predicts this property', OR 'a clear sky in winter always means frost at night' and the absence of clouds to reflect back the Earth's radiation is the basis of such a prediction'.	science. Rather, examples and stories should be given (not philosophical principles) in order to encourage prediction in a range of contexts. For the high ability pupils however, it is important to instil an awareness of the difference between 'rule of thumb' statements (experience) and ideas which underpin and explain such statements.
10 -	be able to demonstrate an understanding of the differences in scientific opinion on some topic, either from the past or present, drawn from studying the relevant literature, for example, plate tectonics and the wrinkling of a shrinking Earth OR living things reproduce their own kind and the spontaneous generation of species.	- The examples chosen should not always be Eurocentric but global. The prime objective should be to illustrate the development of scientific ideas at other times and in other cultures. It should be stressed that science can be developed and practised within a metaphysical framework which is absolute. The latter, based on religious (or other) principles, guides scientific activity.
-	be able to relate differences of scientific opinion to the uncertain nature of scientific evidence, for example, what is the cause of 'cot deaths', OR what is responsible for the death of trees in European forests.	(Refer to the latter parts of Chapters 1 and 2 concerning the Islamic perception of science, where the connection between scientific practice and metaphysical context is discussed in more detail).

My analysis of attainment target 17 shows that very valuable multicultural teaching material can be distilled from its bold statements. Science teachers were encouraged to take on broad social, moral, spiritual and cultural factors when teaching pupils about scientific discovery and technological application. King's College London, for instance, arranged seminars for science teachers and produced examples of materials that could be used for teaching AT17. To a limited extent, the ASE attempted to incorporate some of these elements in their popular Science and Technology in Society Project.

The following supplementary materials shall now be assessed to see how far they conform with this attainment target:

- Science and Technology in Society (SATIS)
- Science in Society
- Science in a Social Context (SISCON)

The SATIS materials of the Association for Science Education have been chosen for analysis because the ASE has been and is involved in seriously studying the progress and impact of science education nationally. Throughout the last two decades, in particular, its initiatives have produced both mainstream and supplementary textual materials that have provided the backbone to many school science syllabuses and the skeletal framework for others. Its views and recommendations have seriously informed the educational decisions taken by government ministers and Working Parties reporting to them.

The questions which arise from this assessment and from the statements themselves - with particular reference to the nature of science - shall form the basis of the fieldwork exercise to be elaborated in the subsequent chapter.



## 4.2 Science and Technology in Society (SATIS) - the mainstream project for Key Stage 4 pupils

### Brief background to the Project

The Science and Technology in society (SATIS) project was set up by the Association for Science Education (ASE) in September 1984. Its fundamental objectives were to relate scientific concepts and content to social, economic and technological contexts, and to look a little more closely at the interactions between science, technology and society.

The main source of inspiration for the project had come from the 1985 Department of Education and Science policy document, Science 5-16: a Statement of Policy, and the 1981 ASE document, Education through Science. It is worthy of note that each SATIS unit has been written by an experienced teacher, often in association with an expert from industry, the universities or the professions.

### The need to teach about science and technology in society

In a world dominated by the manifestations of science and technology, tomorrow's citizens need to be equipped with an adequate understanding of science-related issues such as nuclear power, invitro fertilization, fluoridation of water supplies and food additives. It is a prerequisite, however, to have studied the conceptual content before such issues can be considered and debated in a rational, informed way. Hence the need for SATIS type material to supplement and complement the standard academic science curriculum which often has little time for consideration of such matters.

The humanisation of science, by making it relevant to the lives of the pupils, has been a central aim of the SATIS team. The team recognised that science is often represented in school and in the media, as neutral, objective and impersonal. This, in effect, dehumanises science thereby misrepresenting it, often in a grotesque way. Science is a human activity, carried out by humans and having an impact on the lives of all citizens. Some of the actual methodology of science may be objective, but the practice of science - carried out by subjective individuals - is certainly not.

We live within a global network of cultures, so the SATIS project aims to reflect such diversity. It is of crucial importance to bring home to the pupils that the impact

of science and technology is not confined simply to Britain and the industrially prosperous Western world. The contextualisation of science education should effectively draw attention to this cultural diversity. The impartation of such knowledge and skills is brought about by the interactive approach of discussion, working in groups, role-play, problem-solving activities, reading activities and practical work. That is, a different set of activities from that normally associated with science teaching.

#### Overall aims of the SATIS project

- To show that science is not confined to the school laboratory, but is manifest in all aspects of the world, both local and distant.
- To show that science has a human face.
- To encourage interest in the interactions between science, technology and society.
- To develop awareness of the contributions, both good and bad, made by science and technology to society.
- To develop awareness of industry, its economic basis, how it operates and its role in wealth creation.
- To show the need to consider the impact of technological activity on the environment, and the need to minimise environmental damage.
- To develop awareness of the need for careful use of natural resources.
- To show that science is not an isolated field of inquiry, but interacts with other disciplines, such as geography, economics and history.
- To show that real-life decisions often have to be based on conflicting or inadequate information, that decisions involve compromise, and that there is not always a “right” answer.
- To encourage students to argue on the basis of facts, and to listen to and judge the arguments of others.
- To encourage students to discuss their ideas with others, within a scientific context.
- To provide opportunities to practise certain skills, including reading and comprehension, data collection and analysis, retrieval of information, problem-solving, role-play and communication skills.”

(Reproduced from the SATIS General Guide for Teachers, ASE, 1987, p.5)

Comments on some of these aims in the context of Muslim school science are made in my concluding chapter (8) where I discuss how Muslim science teachers have developed absolutist perspectives in their science teaching.

### Controversial issues

A number of SATIS units are concerned with controversial issues, where the problems discussed transcend the boundaries of science and the “right” answer is a function of one’s espoused beliefs and value system. The General Guide for Teachers produces several arguments, reproduced below, in favour of allowing controversial issues to be considered where they arise naturally from science.

- Many of the issues of the day - for example, pollution, nuclear power, genetic engineering - are rooted in science and technology. To suggest that science is free from controversy is to misrepresent science.
- Consideration of controversial issues benefits from the rational, informed approach which a study of science encourages.
- Social issues such as alcohol abuse may well be discussed in other parts of the school curriculum, but students can benefit from discussing them in the context of a science lesson. Science has a particular way of looking at the world which can give students a useful perspective on an issue.
- Controversial issues can be stimulating, and can motivate students - in particular those who find little to interest them in the traditional content of science lessons.

Admitting that controversial issues place the teacher in a difficult and challenging position, the SATIS project suggests that the most appropriate role for the teacher is that of a neutral chairperson, ensuring that all students can have their say and avoiding the assertion of his or her

own views. The objective is to ensure, in other words, that facts are identified and non-facts made aware. When fact leads to opinion and decision, then we have an interaction with values.

#### 4.3 The ASE Science in Society Project

As a response to mounting concern that science education had done little to demonstrate the relevance of the science learnt in a school laboratory to the world outside the classroom, the Association for Science Education set up the Science in Society Project in 1976. It was believed that there was little understanding in the classroom of the role of industry in society due to the academically parochial background of pure science teachers. Internally, therefore, appropriate and adequate means were not present inside schools to make science more socially relevant and hence combat the tendency of many young people to associate both science and technology with many of the evils in the world - e.g. physics with the bomb and chemistry with pollution.

The aims of the project are to

1. understand the nature and limitations of scientific knowledge,
2. appreciate that the use of scientific knowledge can be both beneficial and detrimental to society and the environment,
3. appreciate that the Earth's resources are finite.
4. understand the need for, and to develop the ability to make reasoned decisions which take account of all relevant constraints; and to recognise that moral considerations are involved in making decisions.

The materials fulfil their assigned aims very well but the content appears to be rather heavy going for most sixth formers. Also, the implications of science discussed throughout the units concerning the environment, Man's future, the relationship between science and religion

etc., are only approached from a predominantly secular perspective, and occasionally Christianity. A global approach is conspicuous by its absence and this, I believe, is a major shortcoming.

#### 4.4 The Science in a Social Context (SISCON) Project

Science in a social context (SISCON) had its basis in a small group of teachers and educationists who formed a steering group in 1978. The ultimate product was eight small books governed by the belief that more emphasis is now being placed on the process by which we find out about science, and somewhat less on the body of knowledge. It was thought that the twin problems of the small number of girls studying science and the lack of opportunity for free expressive writing, may both be related to the load of straight factual material which has to be learnt and an unwillingness to allow pupils to give their own evaluation of the uses and abuses of science.

In the production of these materials the following assumptions were made:

- that the impact of science upon society - and vice versa - is enormous;
- that there is no aspect of life in western societies which is not influenced by, and in many ways dependent upon, science and technology;
- that the direction which science takes, as reflected in priorities and spending decisions, is determined as much by society as by any 'scientific inevitability'.

The primary aim of the SISCON material was to widen the scope of science teaching by helping pupils to arrive at an understanding of some of the critical interactions between society and science. This was done by provoking constructive thought about the challenging and important human aspects of the interaction between science and society.

Topics dealt with by the course include the role of government and industry in science; commercial applications of scientific findings; the role of the scientist in the production of

food; the fight against disease; the development of modern weapons; the responsibility of scientists for the outcome of their work; the effects of science and new technologies on people's daily lives.

“The fact that some of the units raise topics with wide political implications should not be alarming. Sixth Form pupils ought to be aware of these; they will soon be voting citizens. The materials in the course give them a chance to see different aspects of many major problems, so that they can reach their own conclusions. It is hoped that by confronting these problems, pupils will learn to be mature and active participants in their technological society.”  
(SISCON Teacher's Guide, p.8).

The ideas discussed in SISCON Unit II, How Can We Be Sure?, underpin the whole SISCON course. It is emphatically stressed that science does not work by way of deduction. Examples taken from the history of science such as plate tectonics, the electron, the discovery of oxygen and evolution are quoted to show the imaginative nature of speculations, the mechanism which makes things happen, and the stream of new experiments and observations which it generates.

The view put forward is that theories are not proved true by experiment in the literal sense, but are rather used to interpret the observations we make, in fact, influencing our powers of observation. Having established this dimension of uncertainty within scientific explanations, the unit goes on to consider the disagreements between scientific experts who are called upon to give advice on present social issues. The inevitable personal commitment of such scientists is remarked upon.

These views, and the general content of the SISCON materials, are in conformity with the nature of science statements of attainment as expounded in target 17. The moral dimension, however, is not central to the arguments. It is one amongst a number of other dimensions designed to develop and encourage citizen participation in decision-making on technological issues at central, local and protest group level within a secular framework. The following quote exemplifies

this:

“Teaching the necessary scientific understanding of fission is not as difficult as explaining how the decision to drop the bomb was made. It is important that pupils appreciate the scientific, human, political and military implications in this decision because these are all involved in the present disarmament debate.” (SISCON Teacher’s Guide, p.41).

Enlightened secularism appears to be taking the place of a value-oriented religious dimension to science teaching. Taught in the context of a Christian or Muslim science education, the moral dimension would occupy the central ground and other implications - such as political and military - the periphery. We shall see in Chapter 8 powerful associations (at times exaggerated) being made between the content of science lessons and the implications discussed in the context of religious values.

#### 4.5 Supplementary Science Materials in the Context of Attainment Target 17

The requirements of Attainment Target 17 were met, in the main, by many of the ASE SATIS units designed specifically to introduce nature of science themes in the classroom. Although not written with the aim of fulfilling AT 17 requirements in mind, most Science in Society and SISCON units are actually, in my judgement, broadly compatible with a number of nature of science statements. A tabulated presentation, as below, is perhaps the best way to show this.

# UNIT AND CONTEXT IN WHICH ATTAINMENT TARGET 17 IS MET

Statements of attainment associated with LEVEL	SATIS	SISCON	Science in Society
4	2,207: The story of Fritz Haber.	Evolution and the Human Population: Charles Darwin's theory of organic evolution.	Nature of Science: The career of Karl Popper and Thomas Kuhn.
5	In a variety of units where one of the aims is to provide opportunities to practise skills in reading, comprehension, data collection and data analysis.	How can we be sure? The birth of scientific theories.	Nature of Science: The nature of the scientific method and how science develops.
6	7,710: the discovery of DNA.	Energy: The power to work. The predictions of Joule and Faraday concerning the concepts of heat and electricity.	Medicine and Care: Pasteur's work on air-borne organisms.
7	A.T. statements not fulfilled.	Evolution and the Human Population: social Darwinism and eugenics, birth rate.	Population and Health: Malthus and control of the human population.



# UNIT AND CONTEXT IN WHICH ATTAINMENT TARGET 17 IS MET

Statements of attainment associated with LEVEL	SATIS	SISCON	Science in Society
8	A.T. statements not fulfilled.	A.T. statement 1 partially fulfilled in Ways of Living: Babylonian astronomy. Second statement fulfilled in How Can We Be Sure?	Statement 1 not fulfilled. Statement 2 fulfilled in Nature of Science: can science tell the whole truth?
9	A.T. statements not fulfilled.	How Can We Be Sure? Clues, theories and predictions.	Nature of Science: The nature of the scientific method.
10	7,710: living things reproduce their own kind and the spontaneous generation of species. A variety of technological problem solving exercises throughout the course satisfy Statement 2.	How Can We Be Sure? Plate tectonics and the idea of a shrinking Earth.	Looking to the Future: Man and his environment - crisis or climactic.

#### 4.6 The Structure of the National Science Curriculum (England and Wales)

Since the introduction of the National Curriculum in 1989 several revisions have resulted in a substantial part of the original nature of science theme as expressed through AT17 being lost. At frequent intervals we read in the press of Nick Tate, the chief executive of SCAA, saying that the “spiritual, moral, social and cultural” aspects of education need more emphasis in every subject of the curriculum. The new OFSTED Inspection Handbook still states that inspectors must report, as one of five major categories, on “the spiritual, moral, social and cultural developments of pupils at the school”. It specifically mentions “the moral and social issues raised through the study of warfare, the interaction of people, resources and the environment, and the ways in which science and technology can affect our lives” (OFSTED, 1995).

Sir Ron Dearing, in his 16-19 report, states that, even though not a legal requirement as it is below 16, “the spiritual and moral dimensions should be taken into account and consciously included in the curriculum and programmes of young people, and whenever possible in the design and approval of qualifications” (Dearing, 1996).

There can be no doubt that these aims of the school curriculum are now widely seen as central to the teaching of science, as of other subjects. Yet at the same time the new version of Science in the National Curriculum, implemented in September 1996, appears to be moving in precisely the opposite direction. In a recent review of values in the science curriculum, John Bausor compares the current curriculum with earlier versions:

“Compared to the 1991 version there are two highly significant changes:

First, where the 1991 Order speaks about how scientific ideas are “affected by the social, moral, spiritual and cultural contexts in which they are developed” the new one has only “affected by the social and historical contexts”. This looks like a considerable watering down of the original requirement.

Second, the statement in the 1991 Order that “pupils .... should begin to recognise that, while science is an important way of thinking about experience, it is not the only way”, has been completely removed. There are already too many people propagating the pernicious idea that science is the sole source of knowledge (from Richard Dawkins downwards), without the National Curriculum reinforcing it.

It is true that another passage from the general introduction to the KS4 Programme of Study has been modified to read “Pupils should be given opportunities to .... consider the power and limitations of science in addressing industrial, social and environmental issues and some of the ethical issues involved”. Welcome as this is, it is radically different from what went before, and can be interpreted as merely pointing out that science cannot deal with certain aspects of particular problems, not that it is inherently limited in its scope. But surely an important part of teaching science must be to contrast it with other modes of learning and action, and to dispel the notion that “science has all the answers”. ( Bausor, 1996)

Representations from various quarters were made about these points at the drafting stage of the National Curriculum (1996) but to no effect. Some teachers wrote to the Secretary of State for Education (as she then was) to ask for clarification. Bausor says that the answer from a DFE spokesperson addressed the first point, but hardly dealt adequately with the second:

“At the time of consultation the view taken was that cultural, spiritual and moral contexts were among the elements which comprised the ‘historical context’, and that there was no need to spell this out more fully. It was also felt that any study of the ways in which scientific ideas may be affected by their social and historical context would naturally raise the point that such ideas are viewed in the context of other ways of looking at experience. So, once again, it was not thought necessary to spell this out. For these reasons I do not think that anything has actually been removed or played down. There was certainly no such intention.” (Quoted from Bausor, 1996)

To quote from Bausor again:

“This seems like clever mandarin sophistry. What teacher of science, reading the phrase “social and historical contexts” would take it to include “cultural, spiritual and moral”? Most science teachers find such areas difficult to teach, and are not looking for ways to expand their work beyond what is clearly required. It is, of course, good to have the Department’s assurance that there was no intention to remove or play down the original requirement. However, one might reasonably doubt whether this will correspond to how teachers actually see it.” (Bausor, 1996)

There can be no doubt of the importance that SCAA attaches to spiritual and moral curriculum dimensions. This is indicated by the major conference on the spiritual and moral dimensions of the curriculum which it held in January 1996, including a significant input related to science, and other follow up activities since.

The thinking which informed the early stages of developing Science in the National Curriculum recognised that science must not be interpreted in a narrow, knowledge-focused manner. The original four-profile-component version was perhaps best at emphasising that, and successive later versions seem to have moved towards a more traditional stress on mere knowledge. That now seems quite out of keeping with the widely held view that the broader aspects of education must permeate every subject in the curriculum. The following description of the current state of the science National Curriculum brings out this knowledge orientation based as it is on a narrow epistemology.

Substantial changes (truncation and refinement) have been made to the science curriculum over the last eight years. The NC for science is now divided into four attainment targets (ATs) with programmes of study (PoS) relating to each one. In turn, the programmes of study and ATs are divided into four key stages (KS), corresponding to different years of a student's compulsory school life, from year one (age 5) to year 11 (age 16). Each key stage relates to a range of levels (or level progressions) running from level one to ten (see figure 4.1). This section will focus primarily on Key Stages 3 and 4.

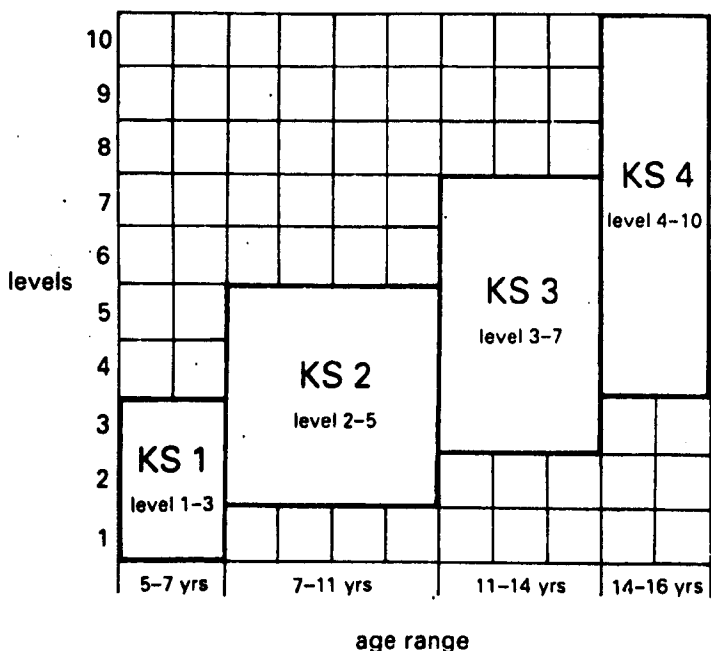


Figure 4.1 Levels, ages and key stages

#### 4.7 Introducing and Analysing the Attainment Targets

##### *Attainment Target 1: Experimental and Investigative Science*

AT 1, scientific investigation, is designed to develop the pupils' investigative skills and their understanding of science through practical activities. These activities, according to the programme of study, should be set within their everyday experience and in 'wider contexts'. During KSs 3 and 4 pupils should gradually become more systematic in their approach, more precise and more quantitative. This should be reflected in their increasing ability to select and use more complex and more accurate measuring instruments and more systematic ways of recording data, including the use of computers. Herein lies the Progression (a key idea in the National Curriculum) in AT 1 at this stage. Pupils will also need to be able to plan and carry out investigations, and this has been a new aspect of practical work for many teachers. The use of science practical work in the past has rarely involved investigational work; more likely proving an existing law or at best a guided discovery lesson have been the norm.

Alongside the PoS sit the statements of attainment and examples in italics intended to clarify them. It is a matter of some debate as to whether teachers actually pay more attention to the SoAs than they do to the Programmes. A cynical view would suggest that if the primary concern of the teacher is for assessment then the SoAs are the focus of attention. These are stated for KS 3 largely in terms of items of behaviour which the pupil will be asked to exhibit - i.e. in behavioural terms such as: carry out a fair test (level 4); formulate hypotheses (level 5); use results to draw conclusions (level 6); and manipulate two or more independent variables (level 7). The problem of how these are actually exhibited in a school lab and how they are to be assessed is an on-going issue for debate amongst teachers - the examples given in the NC document are rarely specific enough to be of practical value. I have been told at more than one meeting of teachers that they would like concrete 'exemplars' of the SoAs in AT 1 - i.e. examples of realistic school science lab investigations during which students can, for example:

- 1      Use a scientific theory to make quantitative predictions (level 9).
- 2      Collect data that enables them to make a critical evaluation of a law, theory or model (level 10).
- 3      Analyse data in a way that demonstrates an appreciation of the uncertainty of evidence (level 9).

Three identified strands run through AT 1 at both KSs 3 and 4 - together they make up the new model of practical work in school science. Practical work should be based on investigations which the pupils (not the teachers) plan and carry out and which involve these three elements:

- 1      asking questions, predicting and hypothesising
- 2      observing and measuring, and manipulating variables

3 interpreting results (the pupils' own results) and evaluating scientific evidence (It is not clear whether this is their own evidence or that of scientists.)

These strands make up practical work at KSs 3 and 4, and incidentally at stages 1 and 2 according to the NC document.

### *Attainment Target 2: Life Processes and Living Things*

This is the AT related to biological principles and processes. Its four main elements are shown in Table 4.2.

Notice that these elements or 'strands' are phrased in terms of pupils' knowledge and understanding, as are those in ATs 3 and 4, as opposed to the more behavioural phrasing of AT 1. The aim here is not to go through the statements in detail but to note that most of the content in this AT is largely derived from traditional biology education. There is perhaps more of an emphasis on ecology, for example, feeding relationships in an ecosystem (level 4); and on the study of pollution, for example, the effects of pollution on the survival of organisms (level 5), than in traditional syllabuses. This is reinforced by the programmes of study in this AT that give further detail on the study required of, for example, the effects of human activity on our air and water, investigations into the local environment, on the nature of waste and the value of recycling, and on the 'major environmental issues facing society'. This AT has obvious links with two of the 'cross-curricular themes', i.e. health education and environmental education, that make up the National Curriculum (the other three themes are economic and industrial understanding, careers education and guidance, and citizenship). To an extent it also links with citizenship, in, for example, the PoS requirement to appreciate that beneficial products and services need to be balanced against harmful effects on the environment.

**Table 4.2: The Science Attainment Targets and their main ‘strands’**

<i>Attainment Target 1: Experimental and Investigative Science</i>	<i>Attainment Target 2: Life Processes and Living Things</i>	<i>Attainment Target 3 Materials and their Properties</i>	<i>Attainment Target 4 Physical Processes</i>
<i>Strand (i)</i> Ask questions, predict and hypothesise	<i>Strand (i)</i> Life processes and the organisation of living things	<i>Strand (i)</i> The properties, classification and structure of materials	<i>Strand (i)</i> Electricity and magnetism
<i>Strand (ii)</i> Observe, measure and manipulate variables	<i>Strand (ii)</i> Variation and the mechanisms of inheritance and evolution	<i>Strand (ii)</i> Explanations of the properties of materials	<i>Strand (ii)</i> Energy resources and energy transfer
<i>Strand (iii)</i> Interpret their results and evaluate scientific evidence	<i>Strand (iii)</i> Populations and human influences within ecosystems	<i>Strand (iii)</i> Chemical changes	<i>Strand (iii)</i> Forces and their effects
	<i>Strand (iv)</i> Energy flows and cycles of matter within ecosystems	<i>Strand (iv)</i> The earth and its atmosphere	<i>Strand (iv)</i> Light and sound
			<i>Strand (v)</i> The earth’s place in the universe



There are also many biotechnological processes and ideas in AT 2, for example genetic engineering, cloning, and artificial selection. These provide opportunities for links with the technology curriculum, for example, fermentation technology. Food production is another area which may be addressed in AT 2, in technology, and in the cross-curricular themes. The extent to which one can create such links is limited, however, as AT 2 is heavily focused on humans and leaves out much traditional non-human biology.

The second strand, on variation, also provides much substance for discussion of controversial issues. With properly structured teaching materials these issues may be tackled with mixed-ability pupils at KSs 3 and 4. Clearly, AT 2 also provides many opportunities for investigations and fieldwork.

Thus AT 2 is one of the more outward looking ATs, with clear links to other parts of the curriculum. To some extent all the ATs involve an element of economic and industrial understanding (theme one), especially in the general requirement in the PoS to consider the application and economic, social and technological implications of science.

### *Attainment Target 3: Materials and their Properties*

As with AT 2, much of this area will be seen as familiar to those who have studied science, this time as chemistry. Thus three of the strands cover the properties, classification and structure of materials and chemical changes. A fourth strand, however, covers 'the earth and its atmosphere', and this may expose areas for which traditionally educated and trained science teachers may be less well prepared. Thus as early as level 4 one of the SoAs includes a knowledge of weathering, erosion and different types of soil. A later statement (level 6) includes an understanding of how different airstreams give rise to different weather as a result of their

passage over land and/or sea. The same level asks for an understanding of the processes that form igneous, sedimentary and metamorphic rocks. At level 7, students are expected to understand how some weather phenomena - such as thunder, fog and frost - are driven by energy transfer processes. Further work on the formation and deformation of rocks is part of level 8, and the weather reappears in level 9 where pupils are asked to explain changes in the atmosphere that cause various weather phenomena. The internal structure of the earth occurs at level 9 and resurfaces in level 10 where pupils, in the last SoA, are required to understand the theory of plate tectonics.

Thus an AT that appeared at first glance in the mass reading of the NC to be chemistry in fact contains elements of meteorology, geology and earth science, and another of the NC subjects, geography. AT 3 is thus the hybrid of the three knowledge-and understanding-based ATs. It links well with the cross-curricular themes, especially economic and industrial understanding (EIU), for example, studies of radiation use in medicine and industry and project work on pollution or water conservation.

#### *Attainment Target 4: Physical Processes*

This is conventionally labelled as the physics component, although it does contain small sections on astronomy and even cosmology and includes the earth's place in the universe. The four main elements of this AT are shown in Table 4.1. Most of the traditional areas of physics education are covered here, such as forces, energy transfer, electric circuits, light and sound, waves generally, motion, magnetism and electromagnetism. There is nothing particularly unexpected here or, as critics would point out, anything post-1900 except perhaps logic gates. It is largely Newtonian and classical. One welcome inclusion is the SoA requiring pupils to know that the earth goes round the sun (level 4). The solar system reappears in level 5, where pupils

are expected to know the times and nature of the planetary orbits. In level 6 they need to know that the solar system is part of a galaxy which in turn is part of the universe. Later, in level 8, they are expected to speculate on conditions elsewhere in the universe, using available data. Satellite motion is covered in level 9, while in level 10 the ultimate statement of attainment requires pupils to relate current theories on the origin of the universe to astronomical evidence - no mean task for a 16-year-old.

Thus AT 4 does contain some ‘untraditional’ elements, though perhaps less so than does AT 3. Most teachers with a physics background will find it to be largely familiar ground. Once again, there is great potential for work related to the cross-curricular themes such as Economic and Industrial Understanding, for example, the role of telecommunications in commerce and industry, the impact of robotics and information technology (IT) on employment patterns, and the future of the nuclear industry.

#### 4.8 The Programmes of Study

We have given an overview of the ATs, largely by considering the statements of attainment. The programmes of study for each area and key stage provide an interesting comparison and sometimes contrast. The general introduction to the programmes for KSs 3 and 4 includes three areas in which pupils are expected to develop:

- 1      **Communication:** This includes the ability both to express ideas and to read ‘purposefully’ and to respond to secondary sources. It also includes the ability to use data from a computer system and an understanding of IT in communication. At KS 4 communication should develop further to include research skills, gathering and organising information from a number of sources, and the use of databases and spreadsheets. Indeed much of the IT skill and knowledge that formed an entire attainment target in the first NC document for

science (old AT 12) are now contained - perhaps less visibly and less obviously - in this part of the PoS.

- 2 The appliance of science: Pupils should develop awareness of the use of science in everyday life and also look at the benefits versus the drawbacks of the application of science and technology. By following a programme of study in this area they should understand 'how science shapes and influences the quality of their lives'. At KS 4 they should go on to consider the use and effects of IT on individuals and society. Eventually, they should appreciate the 'power and limitations of science in solving industrial, social and environmental problems'.
- 3 The nature of scientific ideas: One complete attainment target in the original NC (old AT 17) which disappeared in the new version was concerned with the history and nature of science. For some people this had been a worrying AT because few had education or training in that area; for many, however, it was a challenging AT and a vital component of science education. Whatever the views and arguments, the outcome is that the nature and history of scientific ideas appears partly in the new AT 1, but more obviously in the programmes of study for KS 3 and KS 4 (though not KS 1 and KS 2). In their programme of study pupils should learn about the change of scientific ideas through time by studying the development of some important ideas in science. At KS 4 they should study the *context* in which the pursuit of science takes place - the 'social, moral, spiritual and cultural contexts'. They should learn that science is but one way of understanding the world, albeit an important way.

The nature of science is a vital part of science education, for both teachers and pupils. Indeed, all the areas of the science curriculum outlined in these introductions to the programme of study are felt to be essential elements of a balanced science education. There is a danger, however,

that some teachers will avoid or ignore them in their concern to cover the statements of attainment. This would be a great loss to science teaching.

More detailed programmes of study are given alongside each attainment target. Aspects of the three themes in the general introduction are spelt out in greater detail, for example, the use of IT, applications of the science in that AT, and considerations of the nature of science. Thus in AT 1, the PoS states that pupils should use sensors such as temperature, light and pressure in collecting data. They should use IT in displaying and communicating their own data and in seeking data from other sources. Later, they should look at the limitations of science and critically appraise their own investigation, and explore the nature of 'scientific evidence and proof'.

Unfortunately, the three key themes of the general programme of study, i.e. the communication, application and nature of science, are rather lost in the detailed PoS in ATs 2, 3, and 4. Here, the PoS refers largely to the content rather than the general themes on processes of science. The PoS in ATs 2-4 simply spell out in more detail the content to be covered, largely in terms of the knowledge and understanding required. Contextualisation (nature of science themes) has, in my judgement, been sacrificed on the alter of maximum knowledge transmission. There is hence an inherent imbalance which could be detrimental to developing holistic perspectives in science education.

#### 4.9 The value of a National Science Curriculum

The first benefit of the NC is that it can offer a framework and guidelines for the learning and teaching of science where previously none existed on a national scale. To some extent the science curriculum had been determined perhaps on a local scale (e.g. an Authority), at school level, or in extreme cases by an individual teacher. Thus the NC put an end to what some saw as

a *laissez faire* or do-your-own-thing policy on what science should be taught and to some extent how. Now at least there is some consensus on the curriculum, even if it has been reached with political interference (Graham and Tytler, 1992), though it ought to be noted that GCSE kept a tight rein on syllabus content. Curriculum relativism has come to an end.

In particular, it has been argued, the NC has provided a mandate, a framework and a guideline for teachers in the primary sector (KSs 1 and 2) where previously the situation was far more unpredictable and patchy than in the secondary sector. In the secondary sector at least the content covered was laid down in practice by the public examination syllabuses.

Secondly, it follows from above that two important features of any curriculum have now been made public and explicit. These are 'entitlement' and 'progression'. Both terms have become used widely since the Education Reform Act of 1988. In brief, the first of these terms implies that pupils now have an entitlement, by law, to the 'broad and balanced curriculum' set out in the statutory documents. For many teachers this legal framework or 'right' for all pupils is one of the attractive features of the National Curriculum. Entitlement is often linked with the notion of 'access' for all, i.e. that every opportunity should be given to pupils with special educational needs (SEN) to have *appropriate access* to the programmes of study. This access is their entitlement. The term 'progression' implies that through a structured, published national curriculum pupils will experience continuity and progression as they move from one year to the next, from one teacher to another and even from one school to another. (In practice this is a difficult goal to realise.)

Thus, the introduction of a national, statutory curriculum has provided the possibility of a broad, balanced and carefully planned science education for all pupils (as an entitlement). The introduction of 'new' elements of science such as earth science, astronomy, ecology, and a dash

of cosmology has enriched the traditional curriculum dominated by the big three sciences. Many were disappointed that this extra breadth was reduced in the new version of the ATs, but at least the possibility of greater breadth and therefore balance has increased to some extent. An important addition in broadening science education was the introduction of the nature and history of scientific ideas into the PoS, an innovation latched onto by Muslim schools in particular.

Finally, the introduction of the NC did at least give an opportunity for people to consider why science is taught and what contribution it can make to a person's education. Just over a page is devoted to this in the non-statutory guidance, where six reasons are given for studying science. They will not be repeated here, but surely all teachers should examine why they are engaged in science education: Does it make for better, more well-informed citizens? Does it increase the public understanding of science? Is it of direct utility value to them in everyday living? Will it help them to get a job, or for a very small minority to become a scientist? Does science education, more broadly, contribute to a rounded educated person, capable of an improved understanding of the world? On the one hand, these questions are simply the topic of continuous academic debate. On the other, however, practising teachers could actually improve their lessons by considering why they are teaching what they teach and conveying that message to the pupils.

#### 4.10 Some Difficulties in the National Curriculum

A major difficulty is the task of interpreting the NC and giving it personal meaning. This must be done in order to teach it creatively, lucidly and enthusiastically rather than 'delivering' it. In a sense, the problem is for the mass readership of the NC documents to read the minds and intentions of the small number of people involved in writing them. The problem sometimes degenerates into speculation of the kind: 'I wonder what they were thinking of there?' At other times some of the terms are, by their very nature, problematic. There is no consensus on the

meaning of terms such as generalisation, predictive theory, causal link, variable, hypothesis, validity and model, yet they are freely used in NC documents, particularly in AT 1.

A second problem lies in the wide variation in the size and complexity of the statements of attainment. Some could be mastered in a double lesson, *while others require more extensive analysis for pupils* to begin to get to grips with them. For example, the SoA at level 9 which requires that pupils should understand the relationships between variation, natural selection and reproductive success in organisms and the significance of these relationships for evolution covers a large chunk of one of the most important hypotheses (or is it a theory? ) in science. Contrast this with the ultimate statement of AT 4 which requires an understanding of momentum and its conservation or, at an earlier level, the law of moments.

The third problem lies in the logical mish-mash of the various statements. Some are simply statements of required behaviour, for example, 'be able to ...' Some are statements of skills, for example, 'set up ...', 'select ...', 'manipulate ...'. Some are statements of other processes such as theorising, communicating, speaking and listening. Other statements involve pure factual recall of the 'know that' variety. More confusingly, other statements of the knowledge kind involve far higher intellectual abilities such as understanding, application of knowledge, evaluation and in some cases quite abstract conceptual achievements. This difficulty is partly hidden by the occasional use of the word 'knowledge' when what is required is 'understanding' - and vice versa. When knowledge of terminology is needed it is sometimes at the level of a straightforward naming word, at other times to refer to a process, and occasionally to involve a complex concept such as work or energy (words which also have everyday usages). We must therefore be wary of the mixtures of 'know that ...', 'know how ...', 'understand that ...' and 'be able to' statements in the NC (see Dobson, 1989).



A fourth problem lies in the apparent order or sequence of the SoAs. This problem has several parts.

First, according to the non-statutory guidance (section C8), the ‘conceptual demand of an activity is indicated by the level of attainment’ in a given AT. Yet when experienced teachers examine the document some of the later statements at (say) levels 8, 9 and 10 are actually less demanding than some at earlier levels. In AT 2, for example, the implication is that topics such as photosynthesis and respiration (level 7) are conceptually easier than genetics and evolution (levels 8 and 9). Is this the case? Does it not depend on how the topic is tackled? In addition, some SoAs seem to be inappropriately placed for a particular age group. Thus in AT 3, for example, rates of chemical reaction, which traditionally have been covered well into KS 4, are included at level 7. Moreover, from the children’s point of view, they may reach level 4 in one strand of a particular AT, for example, electricity and magnetism, and level 8 in another strand, for example, light and sound.

Secondly, and more fundamentally, the statements are laid out in a linear, one-dimensional sequence in the National Curriculum document. It may not have been the intention of the working group to suggest that a science course or curriculum should proceed in this linear, sequential fashion. But this is certainly the message conveyed to teachers by the layout of the statements and the numbered levels. Whatever happened to the spiral curriculum? Most school science courses proceed in a cyclical, spiral fashion. Ideas are introduced at one level, discussed in a more refined way later, elaborated further at the next stage, and perhaps quantified at a higher level. This is true of many of the key concepts of science; unfortunately, however, it is not recognised by the structure and layout of the attainment targets and their division into ten seemingly sequential levels.

A collection of statements that may have been seen by the original authors of the National Curriculum as a map of the terrain which should be covered has thus gradually become reified into a sequence of hurdles in a supposedly objective order of increasing conceptual demand. From a pupil's perspective the greatest drawback in seeing coverage of the ATs as mountain climbing rather than orienteering is that for those pupils who do not 'aspire' to the higher levels, large important areas of science education will remain untouched. This practice will prevent the broad and balanced coverage of science, which seemed to be the main benefit of a planned curriculum for all. Thus in AT 2, for example, pupils who do not reach levels 8, 9 and 10 will not cover any of the ideas and theories (or hypotheses?) of genetics and evolution. In AT 4, ideas about the nature and origin of the universe, which fascinate children of all ages, are left to level 10. Yet many would argue that these key ideas could be introduced in some form or other to much younger pupils - this is the essence of the spiral curriculum (Bruner, 1962).

Entitlement breaks down if the curriculum is seen as linear and sequential, rather than cyclical or spiral.

In their enthusiasm for the subject, science teachers may forget that science is just one element of a whole curriculum framework, with a weft and a warp. Additional subjects that make up the subject pillars or warp of the NC are the two other *core* subjects (maths and English) and other foundation subjects (technology, modern foreign languages, history, geography, art, music and PE). Religious education is also a compulsory element. The threads that cross the curriculum framework, the weft, are made up of themes, dimensions and skills. Six skills have been identified in NC documents: communication, numeracy, study, problem-solving, personal and social, information technology. These are skills which teachers of all subjects can develop through their own subject, not least in science education.

#### 4.11 Implications for Muslim Schools Teaching Science

The dimensions of the science National Curriculum are, in a sense, more fundamental since they cover all aspects of equal opportunities and 'education for life in a multicultural society' (NCC, 1992). Thus, for science teachers and pupils, this might involve:

- challenging myths, stereotypes and misconceptions about other people or other societies
- making use of, and building upon, pupils' own backgrounds and experiences
- presenting positive images and role models
- extending knowledge and understanding of various cultures, technologies and faiths
- showing that science itself is not (and has never been) neutral or value-free, but is influenced by the society and the culture in which it is practised
- ensuring equal access for all pupils to science resources and the science curriculum

These dimensions or responsibilities fall upon all teachers. Further research is required in encouraging teachers to reflect upon them and for putting them into practice in science lessons.

Due to their one-dimensional goal of making connections between National Curriculum science and Quranic verses (a central finding of the thesis discussed extensively in Chapter 8), most Muslim science teachers believe that science is not constrained by culture or society; that it transcends these realms and deals instead with universal absolutes. This is how it is taught in Muslim schools (as the results of my research suggest - see Chapters 7 and 8).

Muslim science teachers working in Muslim schools are apparently unaware of the developmental work that has been done on the National Curriculum in science in connection with the dimensions mentioned above. Multicultural and anti-racist teaching methods, for

example, are finally being recalled as essential components of the entitlement curriculum by the Department for Education and Employment (DFEE). Such developments, in my judgement, create new opportunities (and challenges) for Muslim science teachers teaching National Curriculum Science in British Muslim schools.

Non-Muslim organisations seem to have mastered the implications and opportunities heralded by these developments at government level. The Association for Science Education, for instance, has produced an in-service training manual and handbook, both entitled Race, Equality and Science Teaching (ASE, 1991). It begins by presenting science as an inclusive discipline. Steve Thorp, formerly an advisory teacher for multicultural education at Nottinghamshire and now a consultant in the field says,

“The western view of science is as a totally secular discipline, which excludes other viewpoints such as the Islamic idea of science, which is set within a cultural framework. This means that there are many hidden histories of individuals from minority backgrounds whose scientific achievements are not validated because they don’t use the same methodologies as western scientists.” (Quoted in Section 2 of the TES, 27 September 1996)

He goes on to add,

“What we’re saying in the (ASE) handbook is that science can and should be taught within a global context. We see it being done more and more in, say, geography, where teachers are using development education materials. But we have a way to go before we get there in science teaching.”

Michael Reiss, in his ‘Science Education for a Pluralist Society’ has also produced an inspiring account of how multicultural conceptions ought to inform science teaching (Reiss, 1993). Muslim schools, in my view, would benefit from such constructive programmes of anti-racist science education.

The implications for Muslim schools, then, are quite clear. Although Attainment Target 17 (The Nature of Science) has been unceremoniously jettisoned, the DFEE is showing interest in developing multicultural and anti-racist science teaching which at one time was derided as ‘trendy’ and ‘ideological’ and hence banished to the pedagogic wilderness. If Muslim science teachers were to appreciate the full significance of the proposition that the western view of science (broadly speaking) excludes other viewpoints such as the Islamic idea of science set in a cultural framework, then a constructive contribution to the current format of the British science curriculum is possible through the route of multicultural science teaching. For this to materialise, however, a constructive professional liaison of Muslim schools (under the umbrella of the Association of Muslim Schools, or AMS) would have to be established with the Association of Science Education (ASE) and Christians in Science Education (CISE). Even before this can happen, however, raising awareness of nature of science issues amongst the semi-literate (strictly in philosophy of science terms) Muslim school science teaching population is a top priority (see Chapters 7 and 8 for a description of my research findings and analysis of results).

My own research is concerned with a few of the ‘bullet points’ raised above, with a specific interest in the nature of science perceptions held by British Muslim science teachers working in Muslim schools. Over the past three decades research into teachers’ perceptions of the nature of science has been an area of increasing interest, partly the result of Kuhn’s perceptive sociological analysis of the scientific enterprise (Kuhn, 1962). We turn now to a review of some of the methodological instruments that have been used to study nature of science perceptions.

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## **CHAPTER 5**

### **METHODOLOGICAL OPTIONS FOR INVESTIGATING TEACHERS' UNDERSTANDING OF THE NATURE OF SCIENCE**

- 5.1 Significance of Teachers' Perception of the Nature of Science
- 5.2 Teacher Perceptions of Science and Science-Technology-Society
- 5.3 Methods of Inquiry
- 5.4 Further development of methodological tests
- 5.5 Aims of the Fieldwork

## METHODOLOGICAL OPTIONS FOR INVESTIGATING TEACHERS' UNDERSTANDING OF THE NATURE OF SCIENCE

### 5.1 Significance of Teachers' Perception of the Nature of Science

“What science teaching is at any one period of history is determined by the points of view and pedagogical practices passed along through many generations of teachers.” (Woodburn & Oboum, 1965, p.37)

Although written in 1965, this statement holds true today as it did then. Changes in the content and methodology, underpinned by the philosophy, of science teaching are the result of the cumulative expression of new ideas, practices and procedures to those existing previously.

Teaching methodologies reflect the changing attitudes concerning the nature of the pupil, as well as the nature of the learning process. When formally structured such attitudes are often intellectually encapsulated by the prevailing psychological or learning theories. This factor is one of the two powerful influences on the science curriculum. The other is the current philosophy of science. The changing attitude of the nature of science results in a changing attitude towards the nature of the content to be included in the science curriculum, as well as the manner of its presentation.

In 1969, Hurd emphasised that

“the teaching of science in high school should reflect the nature of science as it is known to scientists..... The theories and methods of modern science should be reflected in the classroom.” (Hurd, 1969, p.63)

Hurd is saying something very important. That the philosophy of science must permeate science instruction if science curricula are to adequately reflect the nature of science. A not too promising claim, however, was made in this connection a year later by Elkana who explained that teachers' understanding trails developments in the philosophy of science by up to 30 years.



Indeed, more recently, Billeh and Malik (to whose work we shall refer to in more detail later) have shown that teachers' understanding of the nature of science is little better than that of their pupils. They also add, however, that such understanding can be enhanced through courses and in-service programmes.

It is an educational axiom that if the teaching of science is to reflect the nature of science, then it becomes obvious that the teachers of science must possess an understanding of the nature of science. For, as effectively epitomised by Hurd:

“It is undoubtedly true, a teacher's concept of what science is influences not only what he teaches but also how he teaches.” (Hurd, 1969, p.15)

This implies, on the teacher's behalf, a reasonably sophisticated understanding of the philosophy of science. The new trends in science education generated by the National Curriculum, necessitate an understanding by science teachers of the nature of science. In another statement not bound by time, Carey and Stauss declare in their study about teachers' understanding of the nature of science that:

“If the teacher's understanding and philosophy of science is not congruent with the current interpretation of the nature of science; if the objectives that he establishes are not congruent with the dynamic spirit of science, then the instructional outcome will not be representative of science, in spite of all the efforts that may be expended by those charged with development of relevant curricular materials.” (Carey & Stauss, 1970, p.370)

I believe that teachers' understanding of the nature of science ought to occupy a central position within the arena of science education in general and science teaching in particular. We shall now make a brief excursion into the educational literature to review what work has been done in this connection most recently.

## 5.2 Teacher Perceptions of Science and Science-Technology-Society

Teacher perceptions of the nature of science have been studied regularly for the last two decades. This has, in effect, been a monitoring exercise, identifying any changing teacher perceptions, at times linking it up with changing views on the philosophy of science.

An apparently contradictory conclusion (from mainstream thought) was reached by Lederman in his study of 18 high school biology teachers (Lederman, 1986). His investigative aim was to assess exactly what students and teachers understand about the nature of science and to compare their “understanding” to the notion of an “adequate conception”. He gave the Nature of Scientific Knowledge Scale (NSKS) at the beginning and end of the school year to his randomly selected sample population of 18 teachers and 409 students. The conclusion of the research was that both teachers and students possessed “adequate conceptions” of the nature of science. Lederman points out, however, that possessing an adequate conception of the nature of science does not necessarily indicate a teaching ability which increases students’ understanding of the subject matter. There may thus exist an incongruence between theory and practice, a gap between the teachers’ apparent understanding of the nature of science and the inconsistent methods they may utilise in imparting scientific concepts in the classroom.

In a study quite pertinent to the present thesis, Ogunniyi showed that literate and non-literate Nigerians held both scientific and traditional notions of the world. Persons who had taken a course in the history and philosophy of science, however, showed a preference for the scientific cosmology. With the National Curriculum encouraging nature of science input into science education, the education department mandarins may well learn a salutary lesson from this particular study (Ogunniyi, 1987).

A large study was undertaken by Aikenhead, Fleming, and Ryan to examine the use of various instruments and measurement techniques related to the assessment of the understanding of students about the nature of science. Although it is an assessment of students, the study employs empirical research techniques that can be effectively utilised for a similar assessment of teachers. The general findings of the study were that almost all students saw scientific knowledge as tentative and no students reported that the scientific method was a stepped process as it is so often described. The authors concluded that views of students on science were very diverse but also contradictory, in that their own alternative frameworks sometimes challenged 'orthodox' scientific conceptions (Aikenhead, Fleming & Ryan, 1987).

Research has also been undertaken on how teachers are coping with promoting an adequate understanding of the interdependent relationships among science, technology and society. The impartation of such cross-curricular knowledge requires an understanding of the nature of science and the ways that scientists go about generating new knowledge. The enhancement of this understanding amongst teachers is a continuing concern of science educators (Munby, 1982, for example). A doctoral dissertation and some research reports have considered this issue.

In his doctoral dissertation, Blakely investigated the understanding of the nature of science among 91 middle school teachers in Minnesota. He collected data using the Test of Understanding Science (TOUS) and found that the science teachers scored higher on TOUS than their non-science counterparts. This is not surprising, except that at least 25% of the science teachers failed to correctly distinguish science from technology, and to discriminate between laws, theories and hypotheses. Furthermore, at least a quarter of them also believed that chance and trial and error were major factors in scientific research efforts, and were generally unclear of the overall aims of science.

A survey of science educators in the United States, addressing general issues related to Science-Technology-Society (STS) has been reported by Bybee (1987). The findings of the survey indicated that science educators ranked the following six global problems as the most important STS issues: population growth, water resources, world hunger and food resources, air quality and atmosphere and war technology. They also indicated that most social problems related to science and technology would become worse by the year 2000, and that high schools and colleges were teaching some, but not enough, information about STS issues. The suggestion was therefore that science and social studies aspects of STS issues should be incorporated into one course.

Quite significantly, some recent research papers (Koussidis and Ogden, 1995) and doctoral dissertations (Koussidis, 1987) have cited the need for an increased emphasis on the philosophy of science for science teachers. Without this requisite background, science teachers, in their opinion, run the risk of presenting an inaccurate view of the nature of science, scientific knowledge generation and discernment between science and technology. A sound rationale for the inclusion of Science-Technology-Society themes in science teaching practices has therefore been forwarded by such writers.

It appears from this brief review of recent teacher perception of science research that significant work has been undertaken, and is constantly being monitored, concerning teacher perceptions of the nature of science, as well as the wider implications of the triumvirate Science-Technology-Society. Research journals and doctoral dissertations are understandably bare, however, as far as perceptions of the nature of science of Muslim teachers teaching in Muslim schools are concerned, and how these perceptions are accommodated within the Islamic world-view. This task has been taken up by the present author; we turn first to a review of methods of inquiry that have been adopted by various researchers in this field.

### 5.3 Methods of Inquiry

During the last three decades or so the following methodological instruments have been devised to measure understanding of the nature of science. All these instruments have involved completing a questionnaire by the respondent followed by a semi-structured interview designed to probe further their views about the nature of science. They all, in essence, pose questions about science-based situations from which the authors claim to recognise a 'position' related to their understanding of the nature of science.

#### Nature of Science Scale (NOSS)

29 statements are contained in this scale, and the respondent is allowed to make a response at one of three levels: agree, disagree, or do not understand (or neutral). The model on which the test is based consists of eight aspects of the nature of science. It lacks sufficient reliability and, therefore, the validity of its data has been called into question.

#### Science Process Inventory (SPI)

This deals with the "understanding of the methods and processes by which scientific knowledge is evolved". The SPI has been validated using a rigorous methodological procedure, and testing the instrument for its ability to distinguish among different groups of examinees.

#### Wisconsin Inventory of Science Processes (WISP)

This inventory consists of 93 items, the responses being recorded as "accurate", "not understood", and "inaccurate". In its scoring procedure, the latter two are combined into one response that is opposite to "accurate".

### Test on Understanding Science (TOUS)

This is a four alternative 60-item test. The items are divided into three subscales: (i) understanding about the scientific enterprise; (ii) the scientists; (iii) methods and aims of science.

### Discussion and Criticisms of these methodological instruments

Billeh and Malik (1977) have listed some of the major criticisms of these instruments, although they admit that they can usefully contribute to research in science teaching.

The criticisms are that:

- (i) The instruments are constructed in such a way as to measure individual's knowledge about the scientific enterprise. They do not present situations which require the individual to make judgments based on his understanding of the nature of science.
- (ii) The instruments are loaded with a large number of terms which are beyond the vocabulary level of respondents who use English as a second language.
- (iii) The method of scoring used in some tests (e.g. SPI and WISP) considers "not understood" and "inaccurate" responses as one response. If an individual does not understand a statement, for whatever reason, he is penalised for it, and is considered to have the wrong conception. Consequently, this makes it difficult to identify the level of understanding of each of the components of the nature of science separately.

In the reference quoted, Billeh and Malik attempted to construct a "valid and reliable instrument for measuring the understanding of the nature of science". Using the latter, they investigated the effectiveness of a few science teacher training programmes in Pakistan, in terms of understanding the nature of science.

Although they called their test, Test on Understanding the Nature of Science (TUNS), it did not go much beyond identifying the basic elements of the nature of science using the already established NOSS, TOUS and WISP tests. The final form of their test had the composition:

(1)	Assumptions of Science	(Subtest I)	10 items
(2)	Processes of Science	(Subtest II)	20 items
(3)	Scientific Enterprise	(Subtest III)	15 items
(4)	Ethics of Science	(Subtest IV)	10 items

As they themselves admitted, “the validity of the test followed closely the procedure described earlier for the SPI”.

Because the authors failed to develop anything particularly new, it would appear that they fell victim to some of their own criticisms. The following two questions they posed to the teachers were accorded a correct answer (marked with an asterisk) by the authors which, in my opinion, do not merit an absolute answer. A nature of science questionnaire ought not to be developed in the form of an advanced level multiple choice exercise with a set of predetermined ‘right answers’ for each question. As the philosophy of science shows (Chapters 1, 2 and 8), a variety of positions on the nature of science is both valid and permissible.

(i) A scientist considers a certain theory to be adequate on the basis of:

A - his personal experience

B - his personal likes

C\* - observed facts

D - its usefulness.

(ii) An essential characteristic of a scientific experiment is that it should be:

A - understandable

B - valid

C - supporting the hypothesis

D\* - repeatable.

The “correct” responses (according to the authors) to these questions would necessitate putting the respondent in a predetermined conceptual category. The respondent is therefore penalised, as far as his knowledge of the nature of science is concerned, for not giving a C and D response, respectively, to questions (i) and (ii). We are justified in asking whether these are not philosophical positions from which points of view A or B may be ‘correct’. The nature of the questions is such as to try and measure the teacher’s understanding of the scientific enterprise rather than to present situations which require the respondent to make judgments based on his understanding of the nature of science - a clear contravention of criticism 1. In other words the instrument did not get the subject to illustrate his beliefs by example but asked him to display a knowledge of ‘accepted views’ of philosophy of science.

#### 5.4 Further development of methodological tests

##### Views on Science-Technology-Society (VOSTS)

Aikenhead attempted to overcome the methodological limitations and etymological shortcomings of the tests referred to. (In chronological order: TOUS, Cooley and Klopfer, 1961; NOSS, Kimball, 1965; SPI, Welch, 1966; WISP, University of Wisconsin, 1967). He devised a new generation of standardised instruments to monitor student beliefs about STS topics by use of a large national sample of graduating high-school students (Canadian).



Aikenhead (1987) pointed out that the evaluation instruments TOUS, NOSS, SPI and (he mentions) TSAS (Test of the Social Aspects of Science, Korth, 1968), have one feature in common; namely, that they use objectively scored items. “Some instruments force students to agree or disagree, while others allow for a wider response; for example, strongly agree, do not understand, do not know, and strongly disagree. But in all cases, the tests harbour the implicit assumption that both the student and the researcher perceive the same meaning in the item.”

This is a questionable assumption, which has been referred to by Munby as “the doctrine of immaculate perception” (Munby, 1982). It implies that when the responders process the objectively score item, they subjectively make their own meaning out of the item. The problem then is that the standardised tests that are deemed to be objective by the researcher, turn out to be quite subjective to the respondent (student or teacher). Aikenhead attempted to correct this methodological discrepancy in his research on Canadian high school students by, as he put it, “shifting the responsibility for handling subjectivity to the mature adult researcher”. Through such a technical fix, he maintained that one could discern diversity and insight “objectively” described by students.

Instead of employing a Likert-type scale normally found in standardised instruments, Aikenhead’s study developed an instrument (Views on Science-Technology-Society (VOSTS)), which required students to write an argumentative response to a statement about an STS topic. This methodology was therefore a move away from analysing “right” and “wrong” answers. Rather, it was the students’ arguments that defined various positions or viewpoints on each STS topic.

While VOSTS continues to reflect, as do the earlier standardised tests, the epistemology of science represented in theoretical models from the philosophy of science, it also draws upon investigations in the social context of science which have given additional perspectives on STS.

Such views were, until recently, usually ignored in the philosophy of science literature. The communication of scientists with the general public, scientists and values, the effect of social interactions on knowledge discovered, and socio-scientific decision making, are examples of such social perspectives of science.

In the items for VOSTS, for every statement a converse statement is written, a procedure suggested by Moore and Sutman and taken up by Aikenhead. Sometimes this means casting the statement in the negative, while at other times it means composing the opposite view (see items 1.1 and 1.2 in the Appendix to this chapter). In other cases, several views are required to be expressed (see items 18.1, 18.2 and 18.3, for example). The latter deal with the important problems of the role of facts, moral values and personal motives, respectively, in socio-scientific decision making.

It is necessary to give special emphasis to the wording of items since the readability and clarity of the latter affect the respondent's score on a standardised instrument. The beauty of Views on Science-Technology-Society (VOSTS) is that the problem of potential ambiguity is greatly reduced by the researcher being able to read the student's view, and not having to guess at how the student read the item. The analysis of questionnaire responses involves examining both the overall reaction to the VOSTS statement (expressed by checking "agree", "disagree", "can't tell") and their justification (argumentative paragraph). The doctrine of immaculate perception is thereby effectively avoided.

Even so, as Aikenhead recognises, certain words trigger specific, unanticipated reactions from respondents. His research indicated that the word "accurate" in statement 13.2, for example, was understood by some students to refer to the degree of accuracy of scientific models, rather than the intended notion of the epistemology of scientific models. Likewise, "political climate"

in question 10 was misread as “geographical climate” by some respondents. Precise terms and specific examples should be used wherever possible by researchers to clarify meaning and reduce misunderstandings. There is a trade off, however, as Aikenhead suggests, between specificity which runs the risk of unidirectional responses and generality, which runs the risks of superficiality and amorphous responses. The following passage is self explanatory:

“The specificity/generality problem reflects the imprecision of the English language itself, particularly the imprecise way it is read and interpreted by students. In responding to the VOSTS statements, students formulated arguments drawing upon such common terms as scientific method, scientific fact, tentative scientific knowledge, scientific research, and science and technology; but students used each term in diverse and often contradictory ways. Had the VOSTS been objectively scored, relying on the agree/disagree responses by students, one could easily have seen the “doctrine of immaculate perception” (Munby, 1982) in operation: thinking that students perceive a statement in the same way as the researcher does, and therefore assuming that students would agree or disagree with a statement for the same reasons the researcher would agree or disagree. For example, the researchers agree with statement 13.1 (that scientific models do not duplicate reality) because of their belief in the metaphoric status of scientific models. However, analysis of student paragraphs revealed two distinct reasons for their agreement, reasons that differed from the evaluators’ belief (Aikenhead, 1987): pragmatic heuristics (“models make it easier to learn”), and historical precedents (“models have changed in the past, and so will change in the future”).” (Aikenhead, 1987, p.159)

#### Your own ‘nature of science’ profile - a pilot study

I initially devised my own nature of science questionnaire which was then pilot-tested on my colleagues at the King Fahad Academy (where I work as Head of the Science Department in the Boys’ Upper section).

The starting point here is that the teacher’s own image or view of what science is does have implications for the way that they present and teach science in the classroom - both on content and process. With this in mind some statements on the nature of science were initially formulated inviting a yes/no response.

## The Questionnaire

The aim of the activity that follows is to encourage science teachers to reflect upon their own view of the nature of science. It is intended to be a way of getting you to think, learn and reflect rather than a valid measurement of your position on some sort of objective scale.

Read each of the 24 statements shown below, slowly and carefully. A yes/no response is required. Comments on question formulation will be appreciated.

**Table 5.1: The 24 statements of the pilot questionnaire**

- 1 The results that pupils get from their experiments are as valid as anybody else's.
- 2 Science is essentially a masculine construct.
- 3 Science facts are what scientists agree that they are.
- 4 The object of scientific activity is to reveal reality.
- 5 Scientists have no idea of the outcome of an experiment before they do it.
- 9 The most valuable part of a scientific education is what remains after the facts have been forgotten.
- 10 Scientific theories are valid if they work.
- 11 Science proceeds by drawing generalisable conclusions (which later became theories) from available data.
- 12 There is such a thing as a true scientific theory.
- 13 Human emotion plays no part in the creation of scientific knowledge.
- 14 Scientific theories describe a real external world which is independent of human perception.
- 15 A good solid grounding in basic scientific facts and inherited scientific knowledge is essential before young scientists can go on to make discoveries of their own.
- 16 Scientific theories have changed over time simply because experimental techniques have improved.
- 17 'Scientific method' is transferable from one scientific investigation to another.
- 18 In practice, choices between competing theories are made purely on the basis of experimental results.
- 19 Scientific theories are as much a result of imagination and intuition as inference from experimental results.
- 20 Scientific knowledge is different from other kinds of knowledge in that it has higher status.
- 21 There are certain physical events in the universe which science can never explain.
- 22 Scientific knowledge is morally neutral - only the application of the knowledge is ethically determined.
- 23 All scientific experiments and observations are determined by existing theories.
- 24 Science is essentially characterised by the methods and processes it uses.

These questions were pilot-studied on 10 King Fahad Academy science teachers (five male, five female). The teachers were asked to respond with a yes/no to each of the questions/statements posed. I had to sit with each teacher beforehand to answer their queries. It seemed as though the teachers were more worried about getting the answers 'wrong' rather than treating this as a useful intellectual exercise.

The respondents expressed frustration with questions like number 10, 17 and 22. Some claimed that they needed to have a better grounding in the nature of science before they could attempt such a questionnaire. Others requested a copy of the 'right' response sheet after completion of the questionnaire, and criticised formulation of the questions in the first place when they discovered that no such 'answer sheet' was available or indeed necessary. In short, serious (with hindsight this is perhaps not surprising, as I was their Head of Department) problems were encountered in trying to generate an analysis of response programme.<sup>^</sup> Hence, rather than persisting with the futility of reinventing the wheel, I decided to search for a 'tried out' methodology that would overcome some of the criticisms referred to earlier and be appropriate for my research purposes (assessing Muslim science teacher perceptions of the nature of science). The Koulaidis-Ogborn philosophy of science systemic networks model appeared to fit into this category.

### Philosophy of Science: an empirical study of teachers' views

Koulaidis and Ogborn (1988) have discussed the use of systemic networks as a basis for the construction of a questionnaire. The subject of the questionnaire was teachers' views of the philosophy of science. In this system, various philosophical positions are analysed, and the main philosophical differences represented in a network. The main systems described are inductivism, hypothetico-deductivism (e.g. Popper, Lakatos), contextualism (e.g. Kuhn) and relativism (e.g. Feyerabend).

**The main themes of analysis are:**

**scientific methodology**

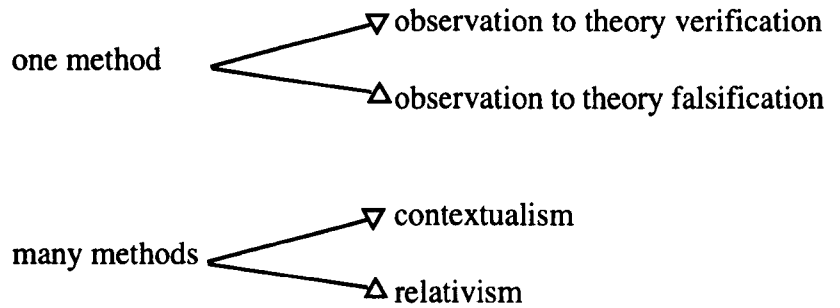
**criteria of demarcation**

**pattern of scientific change**

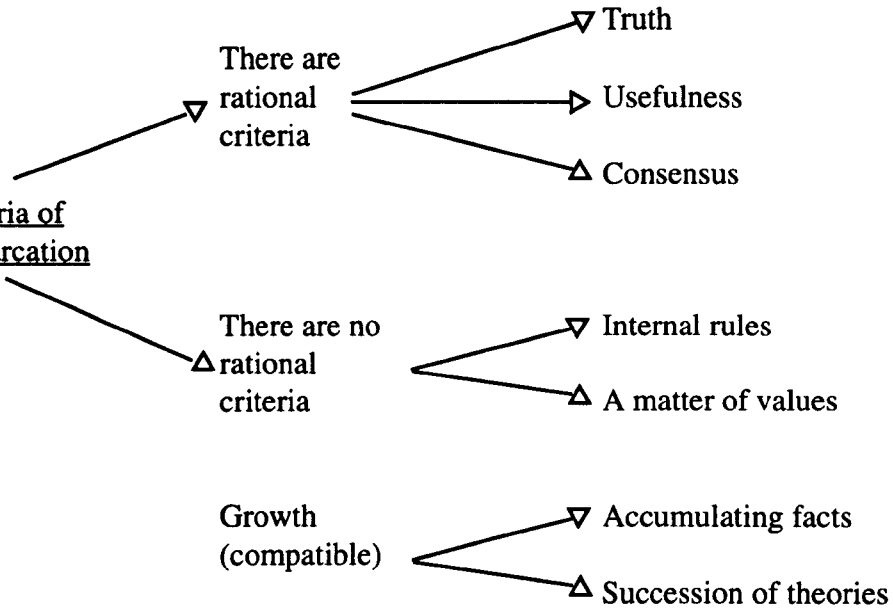
**status of scientific knowledge**

**Each theme is further systematised as follows:**

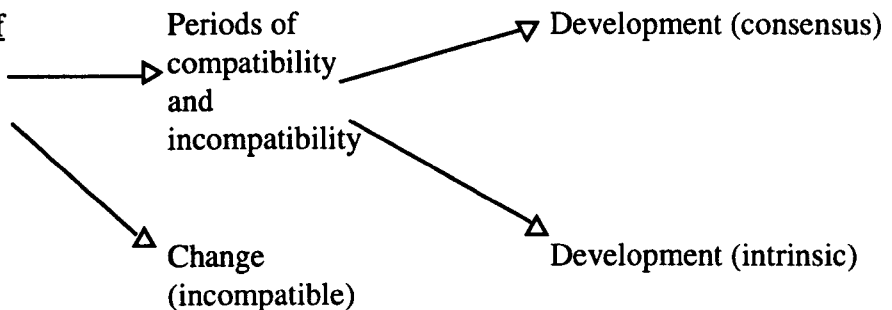
1. Scientific method



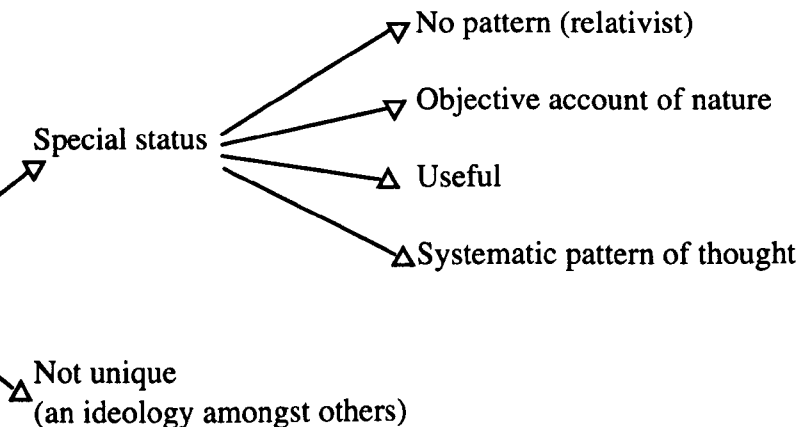
2. Criteria of demarcation



3. Pattern of scientific change



4. Status of scientific knowledge





This schemata is designed to fit respondents into predetermined conceptual categories, in connection with their views about the philosophy of science. The authors quote recognisable accounts of the mainstream of hypothetico-deductive thinking and a contextualist position of Kuhn. For example:

“There is a scientific method, which consists of formulating theories and of attempting to falsify them by experiment and observation. The use of this method is what demarcates science from other, different kinds of knowledge. Done in this way, science progresses, in the sense of getting nearer to the truth. The kind of truth approached is an objective account of the real world.” (Koulaidis & Ogborn, 1988, p.181)

Such a position is an example of one which may be deduced from the analysis of the answers to the questionnaire items. The basic drawback of this method, I believe, is that the doctrine of immaculate perception is disregarded. For each question (see below) the researchers allow the choice of one alternative without asking the respondent to comment on the reason for his or her choice. Conceptual categorisation is an intellectually creditable exercise provided the respondents are encouraged to elaborate, on a simple choice of statement. (See Appendix 2 for questionnaire items.)

The questionnaire was used by Koulaidis and Ogborn to conduct an empirical survey of science teachers' views about scientific knowledge from a philosophical-epistemological perspective. They identified a population of PGCE science students, from particular patterns of responses, as being in agreement or not with a number of broad philosophical positions (referred to earlier as inductivist, hypothetico-deductivist, contextualist and relativist). Certain aspects of their findings, and instrument of analysis, are useful for the fieldwork intended as a component of this thesis.

Their thematic conceptualisation (scientific method, criteria of demarcation, pattern of scientific change and status of scientific knowledge) allows for a reasonable degree of overlap in categorising teacher responses. A substantial minority of PGCE science students who responded to their questionnaire defied straightforward categorisation and the response was classed as eclectic. Such flexibility needs to be at the heart of a nature of science questionnaire design since science teachers, being human, are unlikely to fit neatly into predetermined conceptual categories; and flexibility appears to be a feature of the Koulaidis and Ogborn research instrument.

The theme of scientific method (with its notions of absolute truth and relativistic conceptions) and status of scientific knowledge (special status or ideology amongst others) were thought to provide useful footholds in initiating wider responses from Muslim science teachers about where and how science fitted into their personal world-views. The systemic approach adopted was thought to lend itself well to analysing responses that broached predetermined categories. A contextualist in one dimension may well be a verificationist in another for example. The systemic network conceptualisation of Koulaidis-Ogborn was intended to assist in building a useful conceptual picture of respondents so that relevant questions can then be asked in subsequent interviews, and specific items looked for in classroom observations.

The writers of other instruments looked at tend to presuppose one single valid and universally indisputable model of science. Koulaidis and Ogborn avoid this approach, producing a workable model that was adopted for the purpose of this research.

“This tendency of instruments developed to lack an explicit specification of their philosophical assumptions seems to stem from the fact that most fail to recognise that there are conflicting models of science from a philosophical (and/or a sociological standpoint. This lack of an a priori analysis leaves one with the impression that the writer of each instrument presupposes one single valid and universally indisputable model of science. Here, the distinction between exploratory and normative work is pertinent. It is one thing to propose and/or

defend a certain philosophical system, and quite another, when engaging in exploratory work with the purpose of recording somebody else's views, to obscure the fact that conflicting - and sometimes quite incompatible - systems or thought do in fact exist. This is not to say that one should not engage in both activities. Rather, a clear demarcation line between these two sorts of studies should be drawn." (Koulaidis & Ogborn, 1995, p.277)

## 5.5 Aims of the Fieldwork

The primary aim of the fieldwork endeavour is to elicit the views of Muslim science teachers, teaching in state and independent schools, about the status of scientific knowledge from a philosophical-epistemological perspective. The themes investigated by Koulaidis and Ogborn (1989) appear quite useful to adopt, namely:

- the nature of scientific method
- the criteria of demarcation of science from non-science
- the nature of change in scientific knowledge and
- the status of scientific knowledge

Koulaidis and Ogborn obtained data from teachers who were attending courses intended for those new to the profession and the cohort of science student teachers at the London Institute of Education (academic year 1984-7). Their analytical divisions consisted of male and female physics, chemistry and biology teachers. They found evidence of a general shift of teachers views from the empirico-inductive position often described in earlier work towards a more contextualist view. They further add that

"it would be particularly useful to find out if such a shift could be detected in the views of teachers having wider differences of age and experience than those studied here. The evidence here is that any shift, if it is present, is not uniform with respect to different aspects of science, and seems to vary with the teaching subject of the teacher. Further study of the influence of the nature of the three sciences and their history, in relation to forming views about them, is clearly indicated". (Koulaidis & Ogborn, 1995, p.280)

The views of teachers having wide differences of age and experience may be important, but of equal, if not more, significance in this study are the views of teachers from different religious and cultural backgrounds. The present study intends to undertake just this task and, from the results of the analysis to comment on how such views might affect the teachers' interpretation of National Curriculum programmes of study.

## 5.6 Purpose of the study: Aims, Constraints and Limitations

### Aims

My central interest was to acquire an understanding of Muslim science teacher perceptions of the nature of science and to see if they differ between:

- (a) Muslim and non-Muslim science teachers;
- and (b) Muslim science teachers teaching in state schools and those teaching in Muslim schools.

I was also interested in finding out about the extent to which Muslim science teacher views about the nature of science impact upon their teaching of science.

### Constraints

Being a part-time thesis, I found it very difficult at times to balance my Head of Department responsibilities with the strenuous demands of collating sufficient data and processing results. I was unable to engage myself in re-interviewing respondents who sometimes made interesting, ambiguous, or profound statements well worthy of follow-up. Classroom observation to the extent that I would have liked was also not possible. I was able to observe a dozen lessons over

a period of 18 months as a result of prior negotiation with the administration of the King Fahad Academy. Head of Department and full-time teaching responsibilities meant serious restrictions on visiting other schools for research purposes.

Difficulties were also experienced in negotiating access to institutions at mutually convenient times and for an appropriate length of time. On more than one occasion access had been negotiated with interview and/or classroom observation times set only for the whole arrangement to be cancelled (by the institution) at the eleventh hour (after my arrival).

### **Limitations**

Quite unexpectedly, I found it extraordinarily difficult to negotiate access to Muslim schools for the purposes of conducting classroom observations. Most Muslim female science teaching staff were reluctant to participate, notwithstanding my explanation of the significance of my research for Muslim science education coupled with my personal guarantees of anonymity. 'Purdah' from the outside world was a persistent, frustrating and grinding problem. The teachers were supported in this attitude by the Headteachers and Principals who seemed concerned about the possible ulterior motives of the research. Most teachers (male and female) did not want their lessons filmed and most female teachers did not, in addition, want their voice to be recorded. Often I felt like a cultural outsider in a school community espousing tenets of a faith that I too share. This was the biggest frustration (and concomitant limitation) of all.

### **Selection of subjects**

Five copies of the questionnaires were sent to each of 250 secondary schools in and around London. The package was addressed to the Head of Science with a covering letter explaining

the nature of the research (please see Appendix 3 at the end of this chapter). Many of the schools approached had an institutional link with the Institute of Education, which provided me with a list of 225 schools. The remaining 25 schools to whom questionnaires were sent were the 25 independent Muslim schools, all of whom are affiliated to an umbrella body, the Association of Muslim Schools (AMS).

In total, therefore, 1,250 questionnaires were despatched (to mostly comprehensive and some independent) schools. This was done in the hope of response maximisation. After a great deal of effort expended in writing letters of reminder and/or phone calls, 62 completed questionnaires were returned over a period of 15 months. A sample of 100 was expected and would, of course, have been most agreeable but due to time constraints I had to make a decision and settle for 62.

Processing of questionnaire responses began as the completed forms were received. They were processed in accordance with the Koulaidis-Ogborn model on the SPSS (Social Package for Statistical Sciences) database. The SPSS package and analysis is described in Chapter 6.

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## APPENDIX 1

### VOSTS Statements Used in Aikenhead's Research

#### **Background Information**

Code: \_\_\_\_\_ Age: \_\_\_\_\_ Male \_\_\_\_\_ Female \_\_\_\_\_

#### **Which sciences are you presently studying?**

\_\_\_ Biology \_\_\_ Chemistry \_\_\_ Physics \_\_\_ None of these

#### **What's It All About?**

We want to understand the viewpoints that high school students hold on the complex topic "science, technology and Canadian society". There are about 45 statements covering this topic. We would like to know your viewpoints on ONE of these statements (the one printed below). Each person in your class has a different statement to write about. Thank you for sharing your viewpoint with us.

#### **Instruction to Students**

Please state whether you agree or disagree with the following statement. Then briefly explain your reasons for agreeing or for disagreeing. Two to four sentences should be enough to make your reasons clear. If you cannot agree or disagree, then explain why a choice is not possible for you.

#### **Statement**

[One VOSTS statement fits here.]

**Response:** (check one) \_\_\_ agree \_\_\_ disagree \_\_\_ can't tell

**Reasons:** (Use the reverse side if you need more space.)

#### **Appendix B**

#### **VOSTS Statements Referred to in the Text**

- 1.1 Scientists and engineers should be given the authority to decide what types of energy Canada will use in the future (e.g. nuclear, hydro, solar, coal burning, etc.) because

scientists and engineers are the people who know the facts best.

- 1.2 Scientists and engineers should be the last people to be given the authority to decide what types of energy Canada will use in the future (e.g. nuclear, hydro, solar, coal burning, etc.). Because the decision affects everyone in Canada, the public should be the ones to decide.
- 2.1 Most Canadian scientists are concerned with the potential effects (both helpful and harmful) that might result from their discoveries.
- 2.2 Most Canadian scientists are not concerned with the potential effects (both helpful and harmful) that might result from their discoveries.
- 10.1 The political climate of Canada has little effect upon Canadian scientists because they are pretty much isolated from Canadian society.
- 10.2 The political climate of Canada affects Canadian scientists because they are an integral part of Canadian society.
- 11.1 In Canada, science and technology have little to do with each other.
- 11.2 In Canada, technology gets ideas from science and science gets new processes and instruments from technology.
- 13.1 Many scientific models (such as a model of the atom or of DNA) are metaphors or useful stories; we should not believe that these models are duplicates of reality.
- 13.2 Many scientific models (such as a model of the atom or of DNA) are accurate duplicates of reality.
- 17.1 A scientist may play tennis, go to parties, or attend conferences with other scientists or with non-scientists. Because these social contacts can influence the scientist's work, these social contacts can influence the content of the scientific knowledge he or she discovers.
- 17.2 Although a scientist may play tennis, go to parties, or attend conferences with other

scientists or with non-scientists, these social contacts do not influence the scientist's work, and therefore these social contacts have no effect on the content of the scientific knowledge he or she discovers.

- 18.1 When scientists disagree on an issue (e.g. whether or not low-level radiation is harmful), they disagree mostly because one side does not have all the facts.
- 18.2 When scientists disagree on an issue (e.g. whether or not low-level radiation is harmful), they disagree mostly because of their different moral values.
- 18.3 When scientists disagree on an issue (e.g. whether or not low-level radiation is harmful), they disagree mostly because of their different motives (e.g. pleasing their employers or wanting research grants from the government).
- 19.1 Earning a decent salary is really the main motivation of most Canadian scientists.
- 19.2 Earning recognition from other scientists is really the main motivation of most Canadian scientists.
- 19.3 While earning recognition is important to Canadian scientists, the most important thing is for them to satisfy their curiosity about natural phenomena.
- 21.1 There are justifiable reasons why so many Canadian scientists are male, rather than there being an equal proportion of male and female scientists.
- 21.2 There are no justifiable reasons why so many Canadian scientists are male, rather than there being an equal proportion of male and female scientists.

## **APPENDIX 2**

### **The Koulaidis-Ogborn Questionnaire Items**

Choose one alternative

1. For the different kinds of scientific enquiry:
  - (a) there is basically one scientific method;
  - (b) there are different ways of being scientific in terms of method.
2. The scientific method is to:
  - (a) start from data about a problem, basing hypotheses on the data;
  - (b) start by deducing consequences of theories, checking them against the data.
3. When the consequences of a theory are compared with data, sound conclusions can be drawn:
  - (a) if, and only if, theory and data agree;
  - (b) if, and only if, theory and data disagree.
4. In choosing between different scientific methods for a given problem:
  - (a) there are standards enabling a reasonable choice to be made;
  - (b) there is no rational way of choosing.
5. When there is debate about whether a given theory is to be regarded as 'scientific':
  - (a) there are rational and defensible criteria for making the decision;
  - (b) there are no rational and defensible criteria for making the decision.
6. When there are competing theories and scientists want to decide between them:
  - (a) there are rational and defensible ways of doing so;
  - (b) there are no rational and defensible ways of doing so.

Indicate agreement or disagreement with each statement

7. The existence of various incompatible scientific methods:
  - (a) is a fruitful source of scientific progress;
  - (b) shows the pointlessness of discussions about scientific method.
8. In general the choice of the appropriate method to be used for a given problem:
  - (a) is guided by a consensus of the scientific community;
  - (b) itself belongs within the concept of science;
  - (c) is made by individuals, using their own critical standards.
9. In general the better of two competing theories:
  - (a) is the one which is nearer to the 'truth';
  - (b) is the one which gives the more useful results;
  - (c) is a matter of consensus amongst scientists arising out of critical scrutiny.
10. To be sure of approaching nearer to the truth, one should follow the appropriate scientific method.
11. The search for general rules for deciding between competing scientific theories or which one deserves to be called scientific:
  - (a) is pointless because when theories change so do our ideas about how to decide between theories;
  - (b) is pointless because science merely persuades us to look at things in a certain way, which is no better than any other;
  - (c) is not pointless at all.
12. As science changes or develops, new knowledge generally:
  - (a) replaces ignorance or lack of knowledge;
  - (b) replaces knowledge of another sort.

13. New scientific knowledge arises mainly through:
  - (a) an accumulation of new experiments and observations;
  - (b) a succession of more general and more complete theories.
14. New scientific knowledge:
  - (a) either fits within the existing framework, or generates a new framework incompatible with the old;
  - (b) follows no pattern of growth, being purely the result of what scientists happen to have done.
15. The status of scientific knowledge:
  - (a) is different from other kinds of knowledge, having a characteristic value of its own;
  - (b) is not different from that of any other kind of knowledge, all kinds having equal validity.
16. Scientific knowledge:
  - (a) has particular characteristics in that it attempts to be an objective account of Nature;
  - (b) has particular characteristics in that it is practically useful;
  - (c) has particular characteristics in that it is a systematic pattern of thought.

## APPENDIX 3

### LETTER NEGOTIATING ACCESS TO INSTITUTIONS

Head of Science Department

13 April 1992

Dear Colleague

As part of my personal research programme at the Institute of Education, University of London, I wish to know more about secondary teachers' views of the nature of science, how this view might relate to their personal belief system; and what effects these may have on their teaching of science. This work is being carried out as part of my study for a PhD and is supervised by Dr. Tony Turner in the Science Department of the college.

I am interested to know how understanding of science might be related to or influenced by personal religious belief and in particular how any similarities and differences in such understanding between Muslims and non-Muslims might be related to their personal belief system. I myself work in a Muslim school, interested in the way my school science department approaches the teaching of science in the context of the National Curriculum in our religious context.

To help me with this research I would be grateful if you would:

1. Complete the 18 item questionnaire, which requires only a tick/cross response and might require 30 minutes to complete.
2. Complete the section of the form asking for personal details.
3. If possible, identify yourself and a means of contacting you.

This last piece of information is needed in order to follow up the questionnaire by personal interview with a much smaller sample. If you wish to remain anonymous, please do so if it enables you to respond to the inquiry. My research does depend on being able to interview some respondents.

#### **Guarantee of Anonymity**

The data collected will be used for research purposes only **and will be used in a confidential way in any follow up inquiry**. My thesis and any subsequent publication arising from the work will not identify persons or schools.

I enclose 5 questionnaires for use of as many members of the department as cooperate with the inquiry. Please make extra copies as needed. Returns from science teaching colleagues who are Muslims are particularly important.

Thank you for your time in reading this and for completion of the questionnaire. I would be happy to talk further about the study or related questions.

Please return it to the following address:

N.S. Butt, Head of Science, King Fahad Academy  
4 Bromyard Avenue  
East Action, London W3 7HD

Tel: 081-743 0131 ext 223

## **CHAPTER 6**

### **PROCESSING OF QUESTIONNAIRE RESPONSES ON THE SPSS (STATISTICAL PACKAGE FOR SOCIAL SCIENCES)**

#### **6.1 Introduction**

#### **6.2 Definition of Categories**

#### **6.3 Codes for Analysing Questionnaire on Teachers' Perceptions of the Nature of Science**

#### **6.4 SPSS Results**

#### **6.5 Making Sense of the SPSS Data**



## **PROCESSING OF QUESTIONNAIRE RESPONSES ON THE SPSS (STATISTICAL PACKAGE FOR SOCIAL SCIENCES)**

### **6.1 Introduction**

The SPSS (Statistical Package for Social Sciences) was used to process the 62 questionnaire responses obtained over a period of 15 months. Out of this total, 15 respondents were Muslim science teachers working in Muslim schools, 10 were Muslim science teachers working in state schools, 15 were state/independent school science teachers professing some form of religious belief, and 22 were state/independent school science teachers professing agnosticism or atheism.

The Data Editor (DE) of the SPSS was an appropriate vehicle (after taking professional advice) for processing the results. It is a versatile spreadsheet-like system for defining, entering, editing and displaying data. New data files can be created and existing ones modified with the Data Editor.

In the SPSS data files each row represents a case or an observation. In this research, for example, each individual respondent to the questionnaire was a variable. Each column represents a variable or characteristic being measured. In my research again, each item on the questionnaire is a variable, the length of which is eight characters or less, and each variable name is unique (as duplication is not allowed).

Tables 6.1 and 6.2 below show, respectively, questionnaire items related to the four themes (scientific method, criteria of demarcation, patterns of growth and status of scientific knowledge) and the questionnaire items required to be accepted or rejected for assigning respondents to pre-determined philosophical categories (after Koulaidis & Ogborn, 1989).

**Table 6.1: Items related to the four philosophy of science profiles**  
(after Koulaidis & Ogborn, 1989)

<i>Themes</i>	<i>Items</i>
Scientific method	1a, 1b, 2a, 2b, 3a, 3b, 4a, 4b, 7a, 7b, 8a, 8b, 8c, 10
Criteria of demarcation	5a, 5b, 6a, 6b, 9a, 9b, 11a, 11b, 11c
Patterns of growth	12a, 12b, 13a, 13b, 14a, 14b
Status of scientific knowledge	15a, 15b, 16a, 16b, 16c

**Table 6.2: Items required to be accepted and rejected for assignment of views of respondents to pre-determined categories**

<i>Position</i>	<i>Must accept items</i>	<i>Must reject items</i>
(a) Scientific method		
Inductivism	1a, 2a, 3a	1b, 2b, 3b
Hypothetico-deductivism	1a, 2b, 3b	1b, 2a, 3a
Contextualism	1b, 4a, 7a, 8a or 8b	1a, 4b, 7b
Undecided contextualists	1b, 4a, 7a, 8a, 8b, 8c	1a, 4b, 7c
Relativism	1b, 4b, 7b, 8c	1a, 4a, 7a
(b) Criteria of demarcation		
Inductivism/hypothetico-deductivism	5a, 11c, 9a	5b, 9b, 9c
Rationalist contextualism/Pragmatism	5a, 11c, 9b or 9c	5b, 9a
Undecided rationalists	5a, 11c, 9a, 9b, 9c	5b
Relativist contextualism/Relativism	6b, 11a or 11b	6a
(c) Patterns of scientific change		
Inductivism	12a, 13a	12b, 13b
Hypothetico-deductivism	12a, 13b	12b, 13a
Rationalist contextualism	12a, 12b, 14a	14b
Relativist contextualism	12b, 14a	12a, 14b
Relativism	12b, 14b	12a, 14a
(d) Status of scientific knowledge		
Inductivism/hypothetico-deductivism	15a, 16a	15b, 16b, 16c
Rationalist contextualism/Pragmatism	15a, 16b or 16c	15b, 16a
Undecided rationalists	15a, 16a, 16b, 16c	
Relativist contextualism/Relativism	15b	15a, 16a

## 6.2 Definitions of Categories

Many of the terms used to define the philosophical position of subjects are problematic and a matter of debate. Their meanings change and shift and can be seen as insults or praise depending on to whom you are talking.

Definitions for the meanings are offered below. In doing this I have consulted Bynum et al (1983), Wellington (1989) and Zi man (1980). It is worth noting that Koulaidis and Ogborn in their research (1989) did not attempt to define these philosophical positions for their PGCE subjects, but merely stated them. This is probably due to the inherent difficulties involved in trying to arrive at clear and specific definitions. Instead, as Table 6.2 on p.208 shows, they connected specific questionnaire items (as a combination of acceptance and rejection) with a specific philosophical position on four different philosophy of science profiles (scientific method, criteria of demarcation, patterns of scientific change and status of scientific knowledge). The difficulties I encountered in assigning respondents to predetermined philosophical positions are described in section 6.5 of this chapter.

### Attempted Definitions

#### *1 Relativism/Positivism Axis*

*Relativist:* You deny that things are true or false solely based on an independent reality. The 'truth' of a theory will depend on the norms and rationality of the social group considering it as well as the experimental techniques used to test it. Judgements as to the truth of scientific theories will vary from one individual to another and from one culture to another, i.e. truth is relative, not absolute.

**Positivist:** You believe strongly that scientific knowledge is more ‘valid’ than other forms of knowledge. The laws and theories generated by experiments are our descriptions of patterns we see in a real, external, objective world.

To the positivist, science is the primary source of truth. Positivism recognises empirical facts and observable phenomena as the raw material of science. The scientist’s job is to establish the objective relationships between the laws governing the facts and observables. Positivism rejects inquiry into underlying causes and ultimate origins.

## ***2 Inductivism/Deductivism***

**Inductivist:** You believe that the scientist’s job is the interrogation of nature. By observing many particular instances, one is able to infer from the particular to the general and then determine the underlying laws and theories.

According to inductivism, scientists generalise from a set of observations to a universal law ‘inductively’. Scientific knowledge is built by induction from a secure set of observations.

**Deductivist:** In our definition this means that you believe that scientists proceed by testing ideas produced by the logical consequences of current theories or of their bold, imaginative ideas.

According to deductivism (or hypothetico-deductivism), scientific reasoning consists of the forming of hypotheses which are not established by the empirical data but may be suggested by them. Science then proceeds by testing the observable consequences of these hypotheses, i.e. observations are directed or led by hypotheses - they are theory laden.

### *3 Contextualism/Decontextualism*

*Contextualist:* You hold the view that the truth of scientific knowledge and processes is interdependent with the culture in which the scientists live and in which it takes place.

*Decontextualist:* You hold the view that scientific knowledge is independent of its cultural location and sociological structure.

### *4 Process/Content*

*Process:* You see science as a characteristic set of identifiable methods/processes. The learning of these is the essential part of science education.

*Content:* You think that science is characterised by the facts and ideas it has and that the essential part of science education is the acquisition and mastery of this 'body of knowledge'.

### *5 Instrumentalism/Realism*

*Instrumentalist:* You believe that scientific theories and ideas are fine if they work, that is they allow correct predictions to be made. They are instruments that we can use but they say nothing about an independent reality or their own truth,

*Realist:* You believe that scientific theories are statements about a world that exists in space and time independent of the scientists' perceptions. Correct theories describe things that are really there, independent of scientists, such as atoms, electrons.

### 6.3 Codes for Analysing Questionnaire on Teachers' Perceptions of the Nature of Science

#### Explanation of Codes

The SPSS database required a code (of eight characters or less) to define each philosophical theme and item on the questionnaire. It works as follows:

The code for scientific method is OVERVIEW. For a respondent to be classed as an inductivist, he or she must accept questionnaire items 1a, 2a, 3a and reject items 1b, 2b and 3b.

Statement 1a in the questionnaire (there is basically one scientific method) I have given the code of 'method', 2a (start from data about a problem, basing hypotheses on the data) I have coded 'deduce' and statement 3a (if and only if theory and data agree) has been coded as 'theory'. If statement 1a, 2a and 3a are accepted (method = 0, deduce = 0 and theory = 0 respectively), then the respondent holds an inductivist position for the theme of scientific method.

A similar tactic was adopted for each pair of questions, assigning codes to each feature contributing to a picture of the subjects' position. The codes are as follows:

List of variable codes adopted

<b>Questionnaire Item</b>	<b>Code</b>		
1a	METHOD	10	RIGHT
1b		11a	DECISION
2a	DEDUCE	11b	COMMON
2b		11c	IMPORT
3a	THEORY	12a	IGNORANT
3b		12b	REPLACE
4a	RATIONAL	13a	BUILD
4b		13b	SUCCEED
5a	CRITERIA	14a	NEW
5b		14b	GROWTH
6a	COMPETE	15a	NATURE
6b		15b	DEPEND
		15c	NONSENSE
7a	PROGRESS		
7b	HOPELESS	16a	EXIST
		16b	UNSEEN
8a	CHOICE		
8b	INTERNAL	17a	SPECIAL
8c	MADE	17b	EQUAL
9a	TRUTH	18a	OBJECT
9b	USEFUL	18b	PRACTICE
9c	SCRUTINY	18c	PATTERN

Other useful coding variables were:

GENDER: male - 1, female = 0

AGE:(20-29 = 1, 30-39 = 2, 40-49 = 3, 50 or over = 4)

FAITH: Other (Christian) = 1, none = 2, Muslim = 3

PIOUS: practising = 1, non-practising = 0

TEACHING (length of time in the profession: 1-5 years = 1, 6-15 years = 2, 15 or over = 3

## SPSS FILE

SCIENTIFIC METHOD = OVERVIEW

CRITERIA OF DEMARCATION = DEMARC

PATTERNS OF SCIENTIFIC CHANGE = CHANGE

STATUS OF SCIENTIFIC KNOWLEDGE = STATUS

Compute overview = 0

Compute demarc = 0

Compute change = 0

Compute status = 0

### A. SCIENTIFIC METHOD (OVERVIEW)

If (method eq 0 and deduce eq 0 and theory eq 0) overview = 1

if ((method eq 0 and deduce eq 1 and theory eq 1) overview = 2

If (method eq 1 and rational eq 0 and progress eq 1 and hopeless eq 0 and choice eq 1 and internal eq 0) overview = 3

If (method eq 1 and rational eq 0 and progress eq 1 and hopeless eq 0 and choice eq 1 and internal eq 1 and made eq 1) overview = 4



If (method eq 1 and rational eq 1 and progress eq 0 and hopeless eq 1 and made eq 1) overview  
= 5

### **B. CRITERIA OF DEMARCATION (DEMARC)**

If (criteria eq 0 and truth eq 1 and useful eq 0 and scrutiny eq 0 and import eq 1) demarc = 6

If (criteria eq 0 and truth eq 0 and useful eq 1 and scrutiny eq 1 and import eq 1) demarc = 7

If (criteria eq 0 and truth eq 1 and useful eq 1 and scrutiny eq 1 and import eq 1) demarc = 8

If (competence eq 1 and decision eq 1 and common eq 1) demarc = 9

### **C. PATTERNS OF SCIENTIFIC CHANGE (CHANGE)**

If (ignorant eq 1 and replace eq 0 and build eq 1 and succeed eq 0) change = 10

If (ignorant eq 1 and replace eq 0 and build eq 0 and succeed eq 1) change = 11

If (ignorant eq 1 and replace eq 1 and build eq 1 and succeed eq 0) change = 12

If (ignorant eq 0 and replace eq 1 and build eq 1 and succeed eq 0) change = 13

If (ignorant eq 0 and replace eq 1 and build eq 0 and succeed eq 1) change = 14

### **D. STATUS OF SCIENTIFIC KNOWLEDGE (STATUS)**

If (nature eq 1 and depend eq 0 and exist eq 1 and unseen eq 0) status = 15

If (nature eq 1 and depend eq 0 and exist eq 0 and unseen eq 1) status = 16

If (nature eq 1 and exist eq 1 and unseen eq 1) status = 17

If (nature eq 0 and depend eq 1 and exist eq 0) status = 18

### **KEY FOR SCIENTIFIC CATEGORIES**

2 = hypothetico-deductivism

3 = contextualism

4 = undecided contextualists

5 = relativism

6 = inductivism/hypothetico-deductivism

7 = rationalist contextualism/pragmatism

8 = undecided rationalists

9 = relativist contextualism/relativism

10 = inductivism

11 = hypothetico-deductivism

12 = rationalist contextualism

13 = relativist contextualism

14 = relativism

15 = inductivism/hypothetico-deductivism

16 = rationalist contextualism/pragmatism

17 = undecided rationalists

18 = relativist contextualism/relativism

The VARIABLES are listed in the following order:

Line    1: METHOD DEDUCE THEORY RATIONAL CRITERIA COMPETE PROGRESS HOPELESS  
         CHOICE INTERNAL MADE TRUTH USEFUL SCRUTINY RIGHT DECISION COMMON  
         IMPORT IGNORANT REPLACE BUILD SUCCEED NEW GROWTH NATURE DEPEND  
         NONSENSE EXIST UNSEEN SPECIAL EQUAL OBJECT PRACTICE PATTERN GENDER  
  
Line    2: AGE FAITH PIOUS TEACHING OVERVIEW DEMARC CHANGE STATUS  
-----

```

1  METHOD: 2 2 0 0 0 0 1 1 1 0 1 1 1 1 2 1 0 2 1 1 1 1 1 1 1 0 0 0 1 0 1 1 1 1 0
   AGE: 4 2 1 3      .00      .00      .00      .00
2  METHOD: 1 0 1 0 0 0 2 1 1 0 0 0 0 1 1 1 0 2 1 1 1 1 1 1 1 1 1 0 1 1 0 0 1 1 1
   AGE: 1 2 0 1      .00      .00      .00      .00
3  METHOD: 1 0 0 0 0 0 1 0 0 1 1 0 1 1 0 0 0 1 1 1 1 1 1 0 1 0 0 0 1 0 1 1 1 1 0
   AGE: 2 2 0 2      .00      .00      .00      .00
4  METHOD: 0 0 0 0 0 0 1 0 0 1 1 0 1 1 0 1 0 0 1 1 1 1 0 1 0 1 0 0 0 1 0 1 1 0 1 1
   AGE: 3 2 0 1      1.00      .00      .00      .00
5  METHOD: 1 0 0 0 0 0 1 0 1 1 0 1 1 1 0 0 1 1 1 1 1 1 0 0 0 0 1 1 1 0 1 1 1 0
   AGE: 3 2 1 3      .00      .00      .00      .00
6  METHOD: 1 1 1 1 0 1 1 0 1 1 1 0 1 1 1 1 0 1 1 1 1 1 1 1 0 0 0 0 1 1 1 1 1 1
   AGE: 4 2 1 2      .00      .00      .00      .00
7  METHOD: 0 1 1 0 0 1 1 0 1 1 1 1 0 1 1 0 0 1 1 0 1 0 1 0 0 0 0 0 1 1 0 1 1 1 0
   AGE: 1 2 1 1      2.00      .00      .00      .00
8  METHOD: 1 1 0 0 0 0 1 1 0 1 1 1 1 0 0 1 0 0 1 0 1 0 1 0 1 0 0 0 1 0 1 1 1 0 0
   AGE: 2 2 1 1      .00      .00      .00      .00
-----

```

Respondent 4 recorded as inductivist (1) on scientific method

Respondent 7 recorded as hypothetico-deductivist (2) on scientific method

```

METHOD: 1 1 2 0 0 0 2 2 1 2 2 2 2 1 2 2 1 1 1 1 1 2 1 2 2 2 1 1 2 1 1 1 0
AGE: 3 2 1 2 .00 .00 .00 .00
METHOD: 0 0 2 0 0 0 1 2 1 0 1 2 1 1 2 0 0 1 1 1 1 1 2 1 0 1 0 1 2 1 1 1 1
AGE: 2 2 1 1 .00 .00 .00 .00
METHOD: 1 1 0 0 0 0 1 0 1 1 0 0 1 1 0 0 0 1 1 1 1 1 1 0 1 0 0 0 1 1 0 1 1 1 0
AGE: 2 2 1 1 .00 .00 .00 .00
METHOD: 0 0 0 0 0 0 1 2 2 2 1 1 2 2 2 2 2 2 2 1 1 2 1 2 2 2 2 2 2 1 2 1 2 1 1
AGE: 2 2 1 1 1.00 .00 .00 .00
METHOD: 1 1 0 0 0 0 1 1 1 1 1 0 1 1 1 1 0 0 0 1 1 1 1 0 0 0 0 0 1 1 0 1 1 1 1
AGE: 1 2 0 1 .00 .00 .00 .00
METHOD: 1 0 0 0 0 0 1 0 0 1 0 0 1 1 0 0 1 1 1 1 1 0 0 1 1 0 0 0 1 0 1 0 1 1 0
AGE: 2 2 0 1 .00 .00 .00 .00
METHOD: 1 0 0 0 0 0 0 1 1 1 1 0 0 1 1 0 0 1 1 0 1 1 1 0 1 0 1 0 1 0 1 1 1 1 0
AGE: 2 2 1 1 .00 .00 .00 .00
METHOD: 1 1 2 1 1 0 1 0 1 1 1 0 2 1 0 0 1 0 1 1 1 1 0 1 1 1 2 0 1 2 1 2 2 2 0
AGE: 3 2 1 2 .00 .00 .00 .00
-----
```

Respondent 12 recorded as inductivist (1) on scientific method

```

17  METHOD: 1 0 0 0 0 0 1 0 1 1 1 1 0 1 0 1 0 1 1 1 1 1 0 0 0 1 0 1 1 0 1 1 1 0
    AGE: 2 2 1 2      4.00      .00      .00      .00
18  METHOD: 1 0 1 0 0 0 1 0 1 1 0 1 0 1 1 0 0 1 1 1 1 1 1 0 0 0 1 1 0 1 1 1 0
    AGE: 3 2 1 2      .00      .00      .00      .00
19  METHOD: 1 0 2 2 0 2 2 2 1 1 1 2 1 2 2 1 1 1 2 2 1 1 1 0 0 0 0 2 2 2 2 1 1 1 0
    AGE: 4 2 1 4      .00      .00      .00      .00
20  METHOD: 1 1 0 0 0 0 1 0 1 1 0 1 0 1 1 1 0 1 0 1 1 0 1 0 0 0 1 0 1 1 0 1 0 0 1
    AGE: 2 2 1 1      .00      .00      .00      .00
21  METHOD: 1 1 0 0 0 0 1 0 0 1 1 1 0 1 1 1 1 0 1 1 0 1 1 0 1 1 0 0 0 1 0 1 1 1 1
    AGE: 2 2 1 1      .00      .00      .00      .00
22  METHOD: 1 0 1 1 1 0 1 0 1 1 1 1 0 0 1 2 2 2 1 0 1 1 1 1 1 0 0 0 1 0 1 1 1 1 0
    AGE: 2 2 1 2      .00      .00      .00      .00
23  METHOD: 1 2 0 0 0 0 1 0 1 0 1 1 0 1 1 0 1 1 1 1 1 1 0 1 0 0 0 1 1 0 1 0 1 0
    AGE: 3 3 0 3      3.00      .00      .00      .00
24  METHOD: 0 0 2 0 0 0 1 1 1 1 0 1 0 1 0 0 0 1 0 1 1 1 1 1 2 0 1 1 1 0 1 1 1 1 0
    AGE: 3 3 0 3      .00      .00      .00      .00
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Respondent 17 recorded as an undecided contextualist (4) on scientific method

Respondent 23 recorded as a contextualist (3) on scientific method

```

25 METHOD: 1 0 1 0 0 0 1 0 1 1 1 1 0 1 0 0 0 0 0 1 1 0 1 1 1 0 1 0 1 1 0 1 1 1 1
   AGE: 3 3 0 2      4.00      .00      .00      .00

26 METHOD: 0 0 0 0 0 0 0 0 1 1 1 0 1 1 0 2 0 1 0 1 1 1 1 0 1 0 1 0 1 0 1 1 1 1 0
   AGE: 3 3 0 3      1.00      .00      .00      .00

27 METHOD: 1 0 1 0 0 0 1 1 1 0 1 1 1 1 1 0 1 1 0 1 1 1 1 0 1 0 1 0 1 0 1 1 1 1 1
   AGE: 3 3 0 3      .00      .00      .00      .00

28 METHOD: 0 1 1 0 0 0 1 0 0 1 1 1 1 1 0 1 0 0 0 1 1 0 0 1 1 0 1 0 1 0 1 1 1 1 0
   AGE: 3 3 0 1      2.00      .00      .00      .00

29 METHOD: 1 1 2 0 0 0 1 0 1 2 1 1 1 1 1 0 0 1 0 1 1 1 1 0 1 0 1 0 1 0 1 1 1 1 0
   AGE: 3 3 1 2      .00      .00      .00      .00

30 METHOD: 1 1 1 0 0 0 2 1 1 0 1 0 1 1 1 1 0 2 1 1 1 1 1 1 1 0 1 0 1 1 2 0 1 1 0
   AGE: 2 3 0 1      .00      .00      .00      .00

31 METHOD: 1 1 1 0 0 0 1 0 1 1 1 1 1 0 0 0 0 1 1 1 1 1 1 0 1 1 0 0 1 0 0 0 0 1 9
   AGE: 9 9 9 9      4.00      .00      .00      .00

32 METHOD: 1 0 0 0 0 0 1 0 1 0 1 0 1 1 0 2 2 2 1 1 1 1 1 1 2 2 2 2 2 2 2 2 2 0
   AGE: 2 3 0 1      3.00      .00      .00      .00
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Respondent 25 recorded as an undecided contextualist (4) on scientific method

Respondent 26 recorded as an inductivist (1) on scientific method

Respondent 28 recorded as a hypothetico-deductivist (2) on scientific method

Respondent 31 recorded as an undecided contextualist (4) on scientific method

Respondent 32 recorded as a contextualist (3) on scientific method

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33  METHOD: 1 0 1 0 0 1 1 2 2 2 1 2 1 2 2 1 2 2 2 1 1 2 1 2 1 2 2 2 1 2 1 2 2 1 1
    AGE: 1 3 0 1      .00      .00      .00      .00
34  METHOD: 1 0 2 0 0 1 1 2 2 2 1 2 2 1 2 1 2 2 2 1 1 2 1 2 1 2 2 2 1 2 1 2 2 1 0
    AGE: 1 3 0 1      .00      .00      .00      .00
35  METHOD: 0 2 2 2 0 0 2 2 1 1 1 0 2 2 2 0 0 2 1 1 1 1 1 0 2 0 0 0 1 1 0 1 1 1 1
    AGE: 3 3 0 2      .00      .00      .00      .00
36  METHOD: 1 0 0 1 0 1 1 0 0 0 1 0 1 0 0 1 0 1 0 1 1 1 0 1 1 1 0 0 1 0 1 1 1 1 0
    AGE: 4 4 1 3      .00      .00      .00      .00
37  METHOD: 1 0 1 0 0 0 1 0 1 0 0 0 1 0 0 1 0 0 0 1 0 1 1 0 1 0 0 0 1 1 0 1 1 1 0
    AGE: 2 3 0 2      3.00      .00      .00      .00
38  METHOD: 1 2 2 1 1 0 1 2 1 2 2 2 2 1 2 2 2 1 2 1 2 1 1 2 2 1 2 2 1 2 1 2 2 1 0
    AGE: 3 3 1 2      .00      .00      .00      .00
39  METHOD: 0 1 2 1 0 0 1 0 1 0 1 2 2 1 1 1 2 1 2 1 1 2 2 1 2 2 2 2 2 2 1 1 0 1 1
    AGE: 2 3 1 2      .00      .00      .00      .00
40  METHOD: 1 0 0 0 0 0 1 0 0 1 0 1 0 0 1 1 0 0 1 1 1 0 1 0 1 0 0 0 1 0 1 1 0 0 0
    AGE: 9 3 1 2      .00      .00      .00      .00
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Respondent 37 recorded as a contextualist (3) on scientific method



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41  METHOD: 1 1 0 0 0 0 1 0 1 1 1 0 1 1 0 0 0 1 0 1 1 0 0 1 0 1 0 0 1 1 1 0 1 0 1
    AGE: 9 3 0 1      4.00      .00      .00      .00
42  METHOD: 1 0 1 0 1 0 0 1 0 1 0 0 1 1 0 0 1 1 1 0 1 0 1 2 0 0 1 1 0 1 1 1 1
    AGE: 1 3 1 1      .00      .00      .00      .00
43  METHOD: 1 0 0 0 0 0 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0
    AGE: 2 3 1 1      4.00      .00      .00      .00
44  METHOD: 0 0 0 0 0 0 1 0 0 0 1 0 0 1 1 1 0 1 1 1 1 0 1 0 0 1 0 0 1 0 1 1 1 1
    AGE: 1 2 1 1      1.00      .00      .00      .00
45  METHOD: 1 1 2 0 0 0 1 0 0 1 1 0 0 1 0 0 0 1 0 0 1 1 1 0 1 0 0 0 1 0 0 1 1 1 0
    AGE: 2 2 0 1      .00      .00      .00      .00
46  METHOD: 1 0 0 0 0 0 1 2 2 2 1 1 2 2 2 2 2 1 1 2 1 2 1 2 2 2 2 2 2 2 2 1 2 0
    AGE: 3 2 1 3      .00      .00      .00      .00
47  METHOD: 2 1 2 2 2 2 0 2 0 2 0 2 2 2 2 2 1 2 2 2 2 0 0 1 1 1 1 1 1 0 1 1 1 0 1
    AGE: 2 2 1 1      .00      .00      .00      .00
48  METHOD: 1 1 2 0 0 0 1 2 1 1 0 1 1 0 1 0 0 1 0 1 1 0 1 0 0 1 0 0 1 0 1 1 1 1 1
    AGE: 2 2 1 2      .00      .00      .00      .00
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Respondents 41 and 43 recorded as undecided contextualists (4) on scientific method

Respondent 44 recorded as an inductivist (1) on scientific method

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49  METHOD: 1 0 0 0 0 0 1 2 2 2 1 1 2 2 2 2 1 2 1 1 2 1 2 2 2 2 2 2 1 2 2 2 0
    AGE: 3 1 1 3      .00      .00      .00      .00
50  METHOD: 0 0 0 0 0 0 1 0 0 1 0 1 0 0 0 0 0 1 1 0 1 1 0 1 0 0 0 1 1 0 1 1 0
    AGE: 3 2 0 3      1.00      .00      .00      .00
51  METHOD: 1 0 0 0 0 0 1 0 1 0 1 1 0 1 1 1 0 1 0 0 1 0 0 1 1 0 0 0 1 0 1 1 1 1
    AGE: 3 2 0 2      3.00      .00      .00      .00
52  METHOD: 1 1 0 0 0 0 0 0 1 1 1 1 1 1 0 0 0 1 0 1 1 1 1 0 0 0 0 0 0 0 1 1 1 1
    AGE: 1 1 1 1      .00      .00      .00      .00
53  METHOD: 1 1 0 0 0 0 1 0 1 1 1 1 1 1 0 1 0 1 1 1 1 0 1 0 1 0 1 0 1 1 0 1 1 0
    AGE: 1 3 0 1      4.00      .00      .00      .00
54  METHOD: 1 1 0 1 0 0 1 0 1 0 1 0 0 1 0 0 1 0 1 1 1 1 0 0 1 0 1 0 1 1 0 0 1 0 1
    AGE: 1 3 0 1      .00      .00      .00      .00
55  METHOD: 1 0 1 0 0 0 1 0 1 1 1 0 1 1 0 0 1 1 1 1 1 1 0 0 1 0 1 1 1 1 1 1 1 1
    AGE: 2 2 1 1      4.00      .00      .00      .00
56  METHOD: 1 1 1 0 0 0 1 0 1 1 1 1 0 0 1 1 0 1 1 1 1 1 1 0 1 0 0 0 1 1 0 1 1 0
    AGE: 1 3 0 1      4.00      .00      .00      .00
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Respondent 50 recorded as an inductivist (1) on scientific method

Respondent 51 recorded as a contextualist (3) on scientific method

Respondents 53, 55 and 56 recorded as undecided contextualists (4) on scientific method

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57  METHOD: 1 1 1 0 0 0 1 0 1 1 1 0 1 2 0 0 1 1 1 1 1 0 0 0 0 0 1 0 1 1 1 1 1 1
    AGE: 1 3 0 1      4.00      .00      .00      .00
58  METHOD: 1 1 1 0 0 0 1 0 1 1 0 0 1 1 0 0 0 1 1 0 1 0 0 1 1 0 1 0 1 1 1 1 0
    AGE: 1 3 0 1      .00      .00      .00      .00
59  METHOD: 0 1 1 0 0 0 0 2 1 1 0 1 0 1 1 0 0 1 1 0 1 1 1 0 1 0 1 0 1 1 0 1 1 0
    AGE: 1 2 1 1      2.00      .00      .00      .00
60  METHOD: 1 1 0 1 0 0 1 0 1 1 1 0 1 1 2 1 0 1 1 0 1 1 0 0 0 1 0 0 1 0 1 1 1 1
    AGE: 2 2 1 1      .00      .00      .00      .00
61  METHOD: 1 1 1 1 0 0 1 0 1 1 1 0 1 1 0 0 0 0 1 1 1 1 0 1 1 0 0 0 1 0 1 2 2 2 0
    AGE: 1 3 0 1      .00      .00      .00      .00
62  METHOD: . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
    AGE: . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

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Number of cases read = 62      Number of cases listed = 62

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Respondent 57 recorded as an undecided contextualist (4) on scientific method

Respondent 59 recorded as a hypothetico-deductivist (2) on scientific method

This procedure was completed at 16:50:51

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FINISH.

End of Include file.

## Summary

From processing of the results it appears that Muslim teachers (or non-Muslims for that matter) do not have clearly identifiable and more or less self-consistent philosophical positions. (Quite significantly, a zero is recorded on most occasions for the four primary scientific themes - overview, demarcation, change and status). Only the theme of scientific method was accessible to categorisation, and then only in a third of all cases (21 out of 62). Admittedly, the Koulaidis-Ogborn model uses stringent criteria for identifying a respondent as appearing to agree with a pre-defined position, requiring him/her to have answered all of a number of items according to a defined pattern. Virtually all respondents departed from such patterns, exhibiting philosophical eclecticism. A more thorough interpretation of questionnaire and interview responses has been carried out in Chapter 8.

It is worth noting here that Koulaidis and Ogborn found a slightly different picture with their (smaller) PGCE science students cohort. They write:

“Thus it seems that there is a shift as far as the teachers’ epistemological allegiances are concerned away from empirico-inductivism towards a more contextualist (Kuhnian) view, but that the extent of the movement depends on the theme one addresses:

(a) Inductivists in methodology tend to be rationalist contextualists on demarcation and on patterns of change in science, but are more relativists regarding the status of scientific knowledge.

(b) Contextualists with regard to methodology tend to be more rationalists concerning demarcation and the status of scientific knowledge, these latter two categories also being associated with one another.

(c) Eclectics are in most cases eclectics on all four themes.” (Koulaidis & Ogborn, 1995, p.279)

In my samples, of course, no shifting allegiances were detected on all four philosophy of science profiles (for all science teachers regardless of religious allegiance). They were eclectics through and through. I explain below how one makes sense of the data I collected.

## 6.5 Making Sense of the SPSS Data

To show how difficult it was to categorise respondents into pre-determined philosophical categories, I shall take two respondents - 16 and 28 (an atheist and a Muslim respectively) - and analyse the totality of their responses. The reader is advised to refer to Table 6.2 (p.208) which lists all the questionnaire items required to be accepted and rejected for assignment of views of respondents to pre-determined categories (after Koulaidis & Ogborn, 1989).

On all four questionnaire profiles (scientific method, criteria of demarcation, patterns of scientific change and status of scientific knowledge) both respondents exhibited an eclectic response. In order to be classified as a hypothetico-deductivist, for example, respondent 16 would be expected to accept questionnaire items 1a, 2b, 3b and reject items 1b, 2a and 3a. She accepts item 1a (agreement code = 1, for the statement 'there is basically one scientific method'). A concurrence (code = 1) is also given for item 26 (the scientific method is to 'start by deducing consequences of theories, checking them against the data'). However, the respondent disagrees with item 3b (disagreement code = 0) - 'When the consequences of a theory are compared with data, sound conclusions can be drawn if, and only if, theory and data disagree' - a key hypothetico-deductivist idea. Instead, she accepts item 3a ('...if, and only if, theory and data agree').

Respondent 16 would be expected to reject items 1b, 2a and 3a in order to be classified as a hypothetico-deductivist. Instead, she accepts item 1b ('There are different ways of being scientific in terms of method') thereby contradicting herself as she also accepted item 1a! She did not respond to item 2a (code for no response = 2) and agrees with item 3a ('When the consequences of a theory are compared with data, sound conclusions can be drawn if, and only if, theory and data agree').

To be classified as a hypothetico-deductivist on 'criteria of demarcation' respondent 16 ought to accept items 5a, 11c and 9a, and reject items 5b, 9b and 9c. She accepts 5a ('When there is debate about whether a given theory is to be regarded as 'scientific', there are rational and defensible criteria for making the decision'). Item 11c is rejected ('The search for general rules for deciding between competing scientific theories or which one deserves to be called scientific is not pointless at all'). A disagreement (code = 0) is also registered with item 9a ('In general the better of two competing theories is the one which is nearer to the 'truth'). Although the Popperian concept of verisimilitude (approximation to the 'truth') is rejected, the respondent accepts the proposition that 'in general the better of two competing theories is the one which gives the more useful results' and 'is a matter of consensus amongst scientists arising out of critical scrutiny' (items 9b and 9c respectively). This suggests an instrumentalist/pragmatic and community-oriented (sociological) conception of scientific inquiry. But then when we look for items which must be accepted and rejected for the respondent to be classified as a rationalist contextualist/pragmatist on the profile status of scientific knowledge, for example, we find again that no clear-cut categorisation is possible. In this case items 15a, 16b or 16c ought to be accepted and 15b and 16a rejected. The respondent accepts item 15a ('The status of scientific knowledge is different from other kinds of knowledge, having a characteristic value of its own'), does not respond to 16b (no response code = 2), and rejects 16c ('scientific knowledge has particular characteristics in that it is a systematic pattern of thought'). No response was recorded for items 15b ('The status of scientific knowledge is not different from that of any other kind of knowledge, all kinds having equal validity') and 16a ('Scientific knowledge has particular characteristics in that it attempts to be an objective account of Nature'). The eclectic nature of the responses is probably more to do with, in my view, lack of awareness of nature of science issues rather than a position held with intellectual conviction.



Respondent 16 did not fall into any of the philosophical categories on all four philosophy of science profiles. Respondent 28, however, (a Muslim science teacher) has been classified as a hypothetico-deductivist on the profile of scientific method according to the SPSS database program (see p.221). If we now try to follow this through with the three other philosophy of science profiles (criteria of demarcation, patterns of scientific change and status of scientific knowledge) we run into the same categorisation difficulties as before. In patterns of scientific change, for example, respondent 28 is expected to accept questionnaire items 12a and 13b and reject items 12b and 13a if her tentative philosophical position (hypothetico-deductivist) is to receive confirmation. What we find, however, is that she accepts item 12a ('As science changes or develops, new knowledge generally replaces ignorance or lack of knowledge') but rejects item 13b ('New scientific knowledge arises mainly through a succession of more general and more complete theories'). So the Popperian notion of scientific progression, with which item 13b is directly connected, has been rejected by the respondent. Of the items that are expected to be rejected (12b and 13a), respondent 28 rejects 12b ('As science changes or develops, new knowledge generally replaces knowledge of another sort') but accepts 13a ('New scientific knowledge arises mainly through an accumulation of new experiments and observations'). Perhaps the teacher is thinking of the school science situation where the scientific knowledge of pupils is often enhanced by doing experiments (Attainment Target 1, or Sc1, Experimental and Investigative Science) and not by a sequential process of theory refinement.

To be classified as a hypothetico-deductivist on the profile of status of scientific knowledge, respondent 28 was expected to accept items 15a and 16a, and reject items 15b, 16b and 16c. She actually accepts 15a ('The status of scientific knowledge is different from other kinds of knowledge, having a characteristic value of its own') and 16a ('Scientific knowledge has particular characteristics in that it attempts to be an objective account of Nature'). But she also accepts 15b ('The status of scientific knowledge is not different from that of any other kind

of knowledge, all kinds having equal validity') thereby contradicting herself (having already accepted item 15a). Showing a pragmatic/instrumentalist inclination, respondent 28 accepts (rather than rejects as expected for a hypothetico-deductivist categorisation) item 16b ('Scientific knowledge has particular characteristics in that it is practically useful'). She does, however, reject item 16c ('Scientific knowledge has particular characteristics in that it is a systematic pattern of thought').

The practical difficulties involved in attempting a clear-cut philosophical categorisation should now have been borne out. When views about the nature of science are blurred in the first place due to lack of awareness then, perhaps, clarity is the last thing we ought to expect from the processed responses of a zonal philosophical masterplan.

Further clarification of views and opinions of selected respondents was sought through organising a structured programme of interviewing, followed by some classroom observations in Muslim schools. Chapter 7 describes the strategy I adopted and the results I obtained.

## **References**

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Zyman, J (1980) Teaching and Learning about Science and Society, Cambridge: Cambridge University Press.

## **CHAPTER 7**

### **NATURE OF SCIENCE INTERVIEWS AND CLASSROOM OBSERVATIONS**

- 7.1 Methodological Approach (for interviews and classroom observations)**
- 7.2 Interview Schedule for Nature of Science Thesis**
- 7.3 Field Notes on Interviews with two science teachers**
- 7.4 Post-Classroom Observation Comments by Two Muslim Science Teachers**
- 7.5 Transcript of a Science Lesson in a State (comprehensive) School (Topic: Hormones)**
- 7.6 Comments on the Transcript and Comparisons with Muslim Schools**

## NATURE OF SCIENCE INTERVIEWS AND CLASSROOM OBSERVATIONS

### 7.1 Methodological Approach (for interviews and classroom observations)

After processing of the questionnaire responses, I selected 15 Muslim and 5 non-Muslim science teachers for interview purposes. The subjects were selected on the basis of their availability and readiness to participate after negotiating access with their schools - criteria I had to resort to after encountering serious problems in receiving completed questionnaire responses (62 out of 1,250 dispatched). Negotiating access to interview female Muslim science teachers teaching in Muslim schools was particularly difficult. Married women had obviously made nuptial agreements with their partners to the effect that no unnecessary contact with members of the opposite sex is desirable - though it may be for professional research purposes. This is, in my view, is a cultural rather than a religious phenomenon.

The five non-Muslim science teachers were interviewed as control samples. I made many telephone calls to the non-Muslim science teachers who had responded to the questionnaire. Those who acquiesced were accepted rather than selected for interview.

#### Interview Details

Number of subjects	20
Muslims (state schools)	5 (2 female, 3 male)
Muslims (Muslim schools)	10 (3 female, 7 male)
Non-Muslims (state schools)	5 (3 female, 2 male)

During the interviews (and in some cases during post-observation of classroom practice discussion), I tried to elicit responses from the teachers that would help clarify their positions on their interviews of the nature of science. A detailed interpretation of these responses is discussed in Chapter 8.

I sought permission to have a look at the resources they used in their teaching (books, lesson plans, worksheets). This was done to see whether the views held by teachers about the nature of science are influenced by the resources they use. I was particularly interested in knowing whether Muslim science teachers have their own science education agenda which they use as a framework for teaching National Curriculum science. I observed the set-up of some practical sessions and whether the aim of the lesson illustrated previously taught theory (sometimes, perhaps, in a religious context), or as active learning programmes and open-ended investigations. Occasionally eavesdropping on group talk of pupils helped in teasing out what was getting across to pupils. I also took note of discussions between teacher and pupil; the nature of the questions asked by the teacher, and pupil responses to the questions in the case of two Muslim schools.

Another concern of mine was to look for any value judgements made by Muslim science teachers (in interviewing and classroom observations). I was interested to know whether these judgements are couched within a metaphysical framework, and whether pupils are encouraged to make value judgements concerning ethical issues the science topic has raised. I was able to observe lessons where National Curriculum Key Stage 3 programmes of study were being taught. One lesson was about hormones, and another about the astronomy/cosmology section of KS3. These lessons ('Hormones' in a state school and 'Astronomy'/Cosmology' in a Muslim school) were actually recorded by camcorder (a transcript is included with this thesis). In total five KS3

science lessons were observed (four in a Muslim school taught by Muslim science teachers and one in a state school taught by a non-Muslim science teacher who professes to be an agnostic). I felt that a thorough analysis should be carried out on a few lesson observations than a cursory analysis on many. My genuine difficulties in negotiating access to Muslim schools have already been mentioned.

## 7.2 Interview Schedule for Nature of Science Thesis

It was intended to make use of interviews and conversations as a source of data in schools-based research. The considerable diversity in the form and style of interviewing as well as the product of such an approach have been thoroughly documented. Researchers have approached the interview in so many different ways that broad types of interview can be pointed to. The differences refer to such matters as the nature of the questions asked, the degree of control over the interview exercised by the interviewer, the number of people involved, and the overall position of the interview in the research design itself.

The interview technique adopted was a combination of structured, semi-structured and unstructured. The structured aspect lay close to the questionnaire in both its form and the assumptions underlying its use. At this stage, a high degree of control over the interview situation was required. Results were sought which could form the basis of generalisations. I interviewed 20 practising science teachers: 10 Muslims working in Muslim schools, 5 Muslims working in state schools, and 5 non-Muslims working in state schools. To develop generalised statements fairly large numbers were needed, but constraints of time, energy and cost prohibited this. The questions asked were arranged around a predetermined schedule of questions most of which were short, direct, and capable of immediate responses.

To retain flexibility a semi-structured approach was also needed. In fact this was the predominant approach. It is the one which tends to be most favoured by educational researchers since it allows depth to be achieved by providing the opportunity on the part of the interviewer to probe and expand the interviewee's responses. My aim was to strike a balance between the interviewer (the present researcher) and the interviewee (practising secondary school science teacher), providing room for negotiation, discussion, and expansion of the interviewee's responses.

I intended to allow myself scope to introduce new material into the discussion which I had not thought of beforehand but arose only during the course of the interview (the unstructured aspect). This approach would allow greater scope in asking questions out of sequence and of answering them in different ways. The aim was to provide for a greater and freer flow of information between myself and the respondent. The pre-interview work, of course, had already been done, for it is just as important in using the unstructured interview as it is when using the structured interview to consider beforehand the nature of the encounter and the kinds of general areas I wished to explore.

I made verbal agreements with all 20 interviewees that what they say would be treated with the strictest confidentiality. Their names would not be mentioned in the transcripts I intended to prepare subsequently, and the interview data I acquired would be used solely for my research purposes, that is to say, strictly limited to my thesis.

Ten of the interviews were set up in laboratory preparation rooms (in the absence of the technician!) and ten over the telephone, due to the mutual impracticalities of travelling. To break the ice, I began by asking some general questions (not recorded) about the subject's school, their responsibilities and aspirations. I then began recording and proceeded with the



formal interviewing process. I endeavoured to take control of the interview by asking specific questions at points where I felt the subject could not add anything significant beyond what they had already said. Occasionally the subjects digressed or asked me to rephrase the question often due to the fact, in my view, that they had not, frequently and profoundly, contemplated nature of science issues before. The interviews lasted between 15 and 20 minutes and no serious problems were encountered in their implementation. All interviews were subsequently transcribed. (It is important to stress that these two sets of transcribed interviews are representative of the sample of teachers I interviewed).

### 7.3 Field notes on interviews with two science teachers

#### 1. **A Christian/agnostic science teacher**

This was a science teacher working in a state school who was born a Christian but later developed an agnostic perspective - which he now professes.

[I = Interviewer; S = Subject]

I: Do you think there is such a thing as a scientific method?

S: I think there is one basic scientific method which has to be adjusted to suit different situations that crop up. One universal method that can be adapted.

I: Is it possible, in your opinion, to differentiate scientific statements from non-scientific ones?

S: Science can be distinguished from non-science. Scientific statements would be based on observations which would be followed up by experiments. Where the experiments seem to back the proposed theory, the scientific statement would be valid.

I: So you think there are clear criteria that we can use?

S: In most cases there are clear criteria in distinguishing between science and non-science. In some cases there is a fine line - parapsychology, for example - where it is difficult to distinguish. I think scientific knowledge cannot be absolute. What we know today may not be true tomorrow. We have a consensus among scientists on what we believe today to be scientific knowledge.

I: In your opinion, is science on a path of never-ending progress?

S: I think people make science. We look for answers, we invent methods and equipment to search for answers, we decide what the science knowledge is. Therefore, there are likely to be changes. I think science is beginning to reach a point where the advancements are very fine. I think we've reached a level where we've more or less found limits to new knowledge.

I: Do you try to create occasions in your science teaching where you impart your views about the nature of science to your students?

S: I don't try to get these views across to students but I'm sure they come out from time to time. It is not something I impose. I can't remember any instances where I discussed my views of science or the development of science with my students.

I: In your judgement, does science have a special status in relation to other world-views such as religion for example?

**S:** I believe science has a special status. There is a very difficult transition between science and religion. In religion, the rules are different - not based on observation but on faith, without the questioning environment of science. Although I believe that science and religion can coexist, I believe it is difficult to try and compare the two and answer questions such as is one more valid than the other. It is an impossible comparison; the two fields work on different principles.

**I:** So religion and science are two mutually exclusive departments?

**A:** My views about science must be influenced by my religious upbringing. I do not consciously relate science and religion together. Where the opportunity arises I try and explain that the two are not mutually exclusive.

**I:** In your opinion, can scientific knowledge ever be wrong?

**S:** Science has been a very powerful tool throughout history. Politicians and industrialists have manipulated science for their own purposes. The misuse is related to the applications of science and not to the scientific statements or theories themselves. I don't think knowledge can ever be wrong, for example, knowledge about drugs is not wrong but the use of such knowledge can be.

## **2. A Muslim science teacher**

This teacher works in an independent Muslim school. She was born into a Christian family but later (before marriage) converted to Islam.

- I: Do you think there is such a thing as a scientific method?
- S: I think a number of methods can be adopted in science; it depends on the style of the person doing science.
- I: Is it possible, in your opinion, to differentiate scientific statements from non-scientific ones?
- S: There is no one universal method. But science can be distinguished from non-science. There are clear-cut criteria reinforcing ideas developed in theory through controlled experiments. Some scientific theories are absolute. For example, acceleration due to gravity 'g' is absolute unless we lived in a different universe governed by different physical laws.
- I: Do you try to create occasions in your science teaching where you impart your views about the nature of science to your students?
- S: I try to impart my views about science to my students with some success. I try to talk explicitly about the nature of science.
- I: In your judgement, does science have a special status in relation to other world-views such as religion for example?
- S: I think scientific knowledge can be related to faith; it is not an isolated subject. It does have a special status; but it does not transcend religious knowledge. Religious statements in the Quran are quite revealing - scientifically. Revelation transcends religious knowledge

- it is of greater validity. My views about science are underpinned by my religious faith. I try to impart these views to my students as much as I can. There are areas in the syllabus which lend themselves to such analysis - especially the astronomy part where we can relate science and religion.

[The teacher then referred to the Association of Muslim Schools document reproduced in Chapter 8.]

#### 7.4 Post-Classroom Observation Comments by Two Muslim Science Teachers

Both teachers work in privately funded Muslim schools which have made indefatigable (but unsuccessful) efforts at acquiring Voluntary Aided Status (VAS) and, more recently, Grant Maintained (GM) status. Both teachers made some general comments (with occasional cues from me) after I had observed and recorded (by camcorder) their lesson. In the interests of anonymity, I refer to them as science teachers x and y.

The first teacher (x) is a Key Stage 3 37-year-old science teacher. She acquired her teaching qualifications abroad and has been working in this school for ten years. The second teacher (y) is actually a 35-year-old science trained headmistress. She acquired her teaching qualifications in Britain and has been working in the school for five years. She was a great asset in negotiating access to the school which was initially denied by the Principal (a separate male personality). Both teachers strongly stressed the need for confidentiality as they did not want any leaks about their participation to enter their domestic environments. I reassured them accordingly. (It is important to stress that these two sets of post-classroom comments are representative of the sample of Muslim science teachers I observed).

### **1. Muslim science teacher x**

“We take the Islamic perspective into all lessons, so whichever subject we’re doing - geography, history, science - Islamic perspective is in there usually at the beginning. A lot of topics in the National Curriculum lend themselves to Islamic input - it’s all there already - living things, materials, etc. Some topics are easier to link than others; the linkage is in the process of being formalised across the board. We base our topics around the NC. The Islamic perspective is sometimes integrated into the lesson. Pupils have become very perceptive to this linkage - everything is based on the Quran - Allah’s knowledge is the starting point. Seeds of scientific theories are in the Quran - most definitely. But it must be presented at their level. The Quran definitely contains statements of scientific fact - a lot of things people are finding out today were already pointed out 1400 years ago. The Quran says “Will they not understand? Will they not see?” Who’s not understanding? Who’s not seeing? It’s us of course. Modern science has moved away from the Creator. In the past our scientists were worshippers of the Creator and therefore their science and their knowledge was true. But now I feel there are a lot of grey areas they (scientists) are going into and one that I would not like to be a party of. It is therefore even more important for our children to be aware of this. If you’re not a believer that’s the way you’re going to go.”

### **2. Muslim science teacher y**

“We don’t have any guidelines about linking Islam and science education at the moment, but we do incorporate Islamic principles into science lessons. We follow NC as far as we can go, but there has to be more scope within the NC set aside for Islamic teachings. Astronomy is a classic topic lending itself to Islamic input. Integration is our strategy. We stress in informal meetings to develop the Islamic point of view in science and all other subjects. Teachers find linkage verses in the Quran themselves - we had an INSET about this a year ago. Evolution is taught, discussed and evaluated. We look at all points of view, but we take the verses from the Quran and present it to the children followed by NC requirements. Pupils respond very well - they learn Quranic verses and are at a high level of awareness. I don’t think science is biased; it is

neutral. Seeds of scientific theories are absolutely in the Quran. Things are discussed in the Quran which have only been discovered recently, for example AIDS, a whole tribe was taken away from the earth because of this disease.”

### Comments

These statements are very revealing. It appears that the pedagogy of science teaching in these Muslim schools is highly teleological. A great deal of emphasis is laid on enhancing scientific understanding and awareness in pupils by linking specific National Curriculum statements with Quranic verses remotely related to them. Neither school has any formal documents which highlight ways in which such linkage can be established; all Muslim schools, however, have an Iman (a religious authority) with whom the science teachers liaise in order to fertilise their science lessons with readings from holy scripture. This was the central strategy; the Muslim science teachers were oblivious of the key nature of science themes - methodology, criteria of demarcation, status of scientific knowledge, etc. I have quoted above a few examples, but all the transcripts of interviews of Muslim science teachers tell the same story. More detailed comments of my perceptions are made in Chapter 8.

#### 7.5 Transcript of a Science Lesson in a State (comprehensive) School (Topic: Hormones)

A professional science teacher and a friend (non-Muslim) agreed to take the camcorder, on my behalf, into a Key Stage 3 (Year 9) science lesson at his state school. The teacher observed professed to be an agnostic in his religious disposition and had participated earlier on as a research subject for the questionnaire and interview stages of the research. (He was a 35-year-old biologist who had worked in this comprehensive school for five years.) A 35 minute lesson on ‘Hormones’ was taught to a mixed ability class in a co-educational system. Reproduced below is a transcript of the lesson (a separate video-recording has also been submitted with the thesis).

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# "Hormones" lesson

*Students settle into groups [ ]*

*The teacher calls the register.*

**T:**               What we're going to do today [ ]

*Teacher calls and talks quietly to a student*

The homework you had yesterday. The homework was just going through to make sure that we understand what changes happen to girls when they're starting to become women and going through puberty and that period called adolescence, and also for boys.  
So, let's list them one by one from the homework. We'll start with you, Lauren and we'll work down and by the end we would have run out of space. So mention one change that happens to girls.

**Lauren:**       Period starts.

**T:**               Period starts.

**S:**               Breasts get bigger.

**T:**               Claire?

**Claire:**       Pubic hair grows.

**T:**               Yes. Gemma?

**Gemma:**       [ ] Hips grow out.



**T:** Hips enlarge. Grow out is a bit of a funny expression. Enlarge. Katie?

**Katie:** Don't know.

**T:** Lauren, [ ] Think of one or two things that happens to girls.

**S:** Spots.

**T:** Yes. Spots developing.

**S:** Pubic hair grows.

**T:** Another lot of them? Yes, okay.

**S:** You grow.

**T:** Yes. Well done to you. Yes, you actually grow, yes. There is like a growth spurt. You actually grow. Anymore for girls.

**S:** You put on weight

**T:** Yes, that's part of the re-distribution of weight. That shape tends to have more mass as well. There's one other. You start to get sweatier. Where were we up to - we ran out with you, Katie, really. Boys. Now, this is what changes happens in boys.

**S:** Pubic hair.

**T:** Yes. Layla.

**Layla:** Mmm [ ]

**T:** Some of them are similar.

**Layla:** Voice breaks.

**T:** Yes, voice breaks.

**S:** Gets taller.

**T:** Yes. They get taller.

**S:** They grow up.

**T:** Yes, again.

**S:** Broad shoulders.

**T:** Broad shoulders, yes. Anything else [ ]

**S:** Facial hair.

**T:** Yes. Before you say anything Laura, see if Aisha can say it. [ ]

**S:** The testes produce sperm.

**T:** Testes produce sperm. Anything else. Vickie?

**Vickie:** Penis enlarges.

**T:** Penis enlarges, yes. What else? Anything else happens to boys?

**S:** They get more muscles

**T:** Yes, more muscles.

**S:** Hairy chest.

**T:** More body hair, yes. Okay. So what causes all those changes. It's a big change?

**Ss: Hormones.**

**T: Hormones. This thing called hormone causes it somehow. What else does hormones have to do with, do you know? They have to do with these changes in our bodies, yes? What else does hormones have to do with.**

**S: Your mood.**

**T: When? You've heard of hormones and mood swings. Anything else?**

**S: Feelings.**

**T: Feelings, yes. You sort of feel different. I don't know if this happens to you, it happens to friends of mine, but you feel you mood is a bit ... coming up to when your period is starting. You feel a bit, you know, "leave me alone". Are you a bit like that?**

**Ss: Yes.**

**T: Anything else hormones have to do with?**

**S: To grow.**

**T: To grow, yes. I think we've talked about this before. You know what these parents in America are like. You know America is into that football wear? They wear all those stuff. You've got a parent whose has an athletic son so big or relatively big enough, but there's another guy who's even bigger and fitter. What makes some of them so big is that, now, some of them go to the doctors who are selling them this stuff called human growth hormone. Now, human growth hormone is what we start to produce and it helps us to grow. Guess when we produce most of it? Somewhere around adolescence years you start producing some. You're producing all the time.**

What do you think would happen to someone small who had an injection of it or had it injected? They start to grow. So, when do you think doctors normally use human hormone on them? What sort of people would normally get it?

**S:** Small people.

**T:** Yes. People who's got some sort of problem. It might be, remember, what is it that passes on from cell to cell? From mothers to sons? And what passes on?

**Ss:** Genes.

**T:** Yes, genes pass on. What would happen then if the gene that you got passed on from your mum and dad didn't make growth hormone properly or didn't make enough of it?

**S:** You'd be small.

**T:** You'd be stunted So, doctors can actually measure that now and start giving you growth hormone so you can start to catch up and start to grow normally, right?  
What these parents are doing is to go to doctors who are prepared to sell this particular hormone and their sons are getting injections of it, and, instead of being like a college football player, and if they are really good, they go and play for a proper team and they're injecting this stuff instead of being this big - they're like this big, you know, and that's what they're doing.

**S:** Is that legal?

**T:** In America, it's still legal but there's this federal drugs thing, they're trying to get it banned..  
You must have heard, most people have heard of this other hormone type substance.

**S:** Steroids.

- T:** Yes. What does that do? Do you remember what it did to Ben Johnson?
- S:** You get moodier.
- S:** You get more muscular.
- T:** Yes. You get more moodier and more aggressive but the thing that they say it really does for an athlete is that it means that you can actually train harder. What normally happens when you train for something, when you try to train for something, you get tired and you think, phew! Yes, but if you have this hormone, you can train harder and go longer, so what's now going to happen your muscles if they are being used on and on?
- S:** They get bigger.
- T:** Yes, they're going to grow more and more. So it doesn't give you more muscles like an injection, like in a cartoon - dum, dum -. What it means is that you can train harder and you can develop more and more muscles, and there's something about moods as well.
- T:** It tends to make you a little more aggressive. So, it releases testosterone. This is a male hormone which makes you more aggressive and there's been some suggestions, I don't know if you read about it, but some female athletes have taken some of these.  
What do you think would happen to a woman who takes some of these male type hormone for...
- S:** .....
- T:** Think about it. What do you think would happen if you have these male type hormones and you're a woman?
- S:** People would think you're a bloke.

**T:** So, what sort of thing would you expect to see? What would you look like in the body?

**S:** More muscles.

**T:** More muscles in the body and arms.

**S :** More hair.

**T:** More hairy body possibly. What might happen to the breast.

**S:** They would get smaller.

**T:** Yes, they would get smaller. Have you got the idea.

**S:** And stop menstruating.

**T:** Yes, stop menstruating. This is some of the signs. This is what they've detected.

.....

**T:** So, you can see that hormone must control all of this. Yes? But men must have a different set of hormone to women, mustn't they? Because if they've given women the men type ones they get some of the male type characteristics. Yes? What would happen if you did it the other way round? If you gave a man a woman's hormone, what would happen?

**S:** Breast.

**T:** Yes. Breast will start to grow.

**S:** Not producing eggs.

**T:** Not producing eggs, no.

**S:** Stop producing sperm.

**T:** The sperm production might go down, yes? And what they found in this was on one of those Environment programme on TV, which you might have seen or not, I don't know if you saw it, that the detected chemicals in water just in ordinary drinking water that behaved a little bit like female hormone, you know. These chemicals just have a similar effect on your body to what a female hormone would, because what they first noticed was that if you take a sample of semen and see how many sperms that are actually in it, and how vigorous and good swimmers they are, you can never count it. It measures how fertile you are. If you have a billion of them and they're really swimming that's fertility.

They've noticed that fertility in the west of Britain has gone down at the moment. It's not that they're producing less semen, it's that the sperms are not as healthy. There's not as many and they don't swim so vigorously and, they're trying to work out what's happening here. They started to test the water just in the rivers and they found these chemicals that are just pollutants from factories and things you make and they behave just like female hormone and not only does it affect people who drink them over the years, it's also affecting the fish.

So, the male fish aren't behaving properly like male fish anymore. They're behaving more like female fish. I'm not saying these producing eggs, do you understand, but these are not successfully producing their version of sperms.

Some hormones make a lot of changes in your body. Female hormone do one set of things and male hormones do another set of things. Did anybody find the name of any of these hormones, what we call.

Did anyone find out in their homework. No? Nobody did.

**What else does it control in you. This happens once in a monthly cycle, about once every 28 days.**

**S: Menstruation.**

**T: Yes. Menstruation hormones control your menstrual cycle. What's released from your ovaries every month?**

**S: An egg.**

**T: What's the proper word for an egg?**

**S: An ovum.**

**T: An ovum. An egg is released every month, right? How does the egg know to be released? Its sentence is up.**

**S: Some hormone.**

**T: Some hormone. There must be some sort of signal that allows the egg to be released, yes? If the egg isn't fertilised, what happens to the egg?**

**S: It dies.**

**T: It dies, yes. Is your body in anyway prepared for the egg? In what way is it prepared?**

**S: The lining.**

**T: It's like a lining with lots of blood going into it and, what would happen if the egg was fertilised? What would that lining be for?**

**S: For the baby.**



**T:** So, the egg would implant into it and the embryo would start to grow and feed in there, yes? But if the egg isn't fertilised, it just shrivels and dies.  
But what about the lining?

**S:** It gets rid of it.

**T:** The body gets rid of it. So, how does the body know to keep it or to get rid of it?

**S:** Hormone.

**T:** There must be another hormone, another sort of chemical signal saying, "keep it" because it is fertilised or it's not fertilised, so let it go. We're going to make some notes on how this cycle of hormones work. [ ]

*Students prepare to take notes*

**T:** Call it, Hormones, rather than just a control of menstruation because it means we can talk about it.

Aisha, what are they? Hormones? If you could see some, what would they be like? Little cells or what do you think they'll be? Or like some sort of liquid? What will they be like?

**Laura:** They can inject it.

**T:** Yes, if they can inject it, what must it be? It must be some sort of liquid. So, what are liquids, chemicals. So, hormones must be some sort of chemical.

**T::** Hormones are chemicals. (*dictating*)

Do you think humans just have them?

**S:** No.

**T:** What else?

**S:** Animals. Plants.

**T:** Do you think plants do as well?

**Lauren:** Yes. To drop their leaves.

**T:** Yes, you're right, Lauren. It's the same question, how do plants know in the autumn to drop their leaves? How do they know? How do they know to grow towards the light? I mean, there must be some sort of chemicals influencing what happens with them.

**T:** So, chemicals produced by animals and plants...(dictation:)

**T:** .. . to what?

**S:** To control changes.

**T:** It's always changes because you know when you get really excited or something, is it just your brain that does that?

**S:** Your heart.

**T:** What happens to your heart?

**S:** It gets faster.

**T:** Yes, you're heart struck and what about your skin?

**S:** Gets sweaty.

**T:** Gets sweaty. So, it's not change, it's lots of things like activities or something.

**:** ...to control activities within the organism. (dictating)

- T:** Now, I don't think it's going to be hard for you to guess where you produce some of your, some of your specifically female hormones. I think you probably might guess that. Where do you think some of them get made? Female hormones. Where do you think they're made? Wherever it is males haven't got this, so they don't make them. A reasonable place for sending these chemical signals out.
- S:** Uterus.
- T:** Uterus. Yes and in the male, where would it be?
- S:** Testicle.
- T:** Yes, in the testicles. We're going to write that. I thought you'd know that.
- T:** Ovaries and testes act as glands and produce some of the sex hormones. (*dictating*)
- T:** Now, I haven't finished the sentence yet, but if the ovaries produce the hormone and this is sort of liquid and the ovaries are sending a signal to the uterus when the egg is released, let's say, so, the lining stays - these are ready for the egg. How does the chemical get from the ovaries to the uterus.
- S:** By tubes.
- T:** You think there's tubes all over your body? It would seem a reasonable way to do it. If the gland's just put into the bloodstream, where has the blood eventually got to get to?
- S:** Everywhere.
- T:** Yes. It goes everywhere, doesn't it? So, eventually it's got to go to the gland that was sending the signal. Yes? So, what have I said so far?

- T:** Which like all hormones, pass into the bloodstream until they reach. (*dictating*)
- T:** What did you say Claire? Until they reach?
- Claire:** The organ.
- T:** Until they reach the organ which will respond.
- T:** Let's say what the glands are called, they've all got a family name.
- T:** These hormone producing glands are called Endocrine Glands.
- T:** Now, can anyone remember from when we did those chemical reactions, what the prefix Endo means? It's a hard one. I'll give you a really heavy clue on this. When we said the reaction was Exothermic, it meant it gave heat out as it was happening. You know when you strike a match, it is endothermic or exothermic. It gives energy out.
- S:** What does endo mean?
- T:** If exdo means out, endo means in. So, tell me where are the hormones put? Are they put outside the body or inside the body?
- S:** Inside.
- T:** Yes. They secrete their hormone into the blood - endo.
- T:** And the place [ ] they're at is called target tissue. [ ]
- T:** So, where do male produce male sexual hormones?
- S:** Testicles.

**T:** Yes. Let's list some of the things that has happened when these hormones start to produce. What happens to men?

**S:** Their voice break.

**T:** Their voices break. What do you think then is one of the target tissue for the male sexual hormones for this.

**S:** The larynx.

**T:** The larynx. What else starts to happen to the male?

**S:** Their shoulders broaden.

**T:** Yes, their shoulders broaden. So, where is the other target tissue? This sort of bone and muscle tissue. When those body hair starts to grow. So, another target tissue is these little cells which helps to grow hair. So, can you name some target tissue for your hormone which you start to produce. Yes?

**S:** (not very clear???)

**T:** These ??? tissue starts to grow. This is a target tissue.

**S:** Pubic hair

**T:** Okay. So, there's body growth target tissue. Any idea? So, target tissue isn't necessarily anywhere the gland is?

**S:** No.

**T:** Target tissue can be anywhere, yes? We think that definitely when we get excited or frighten there's some hormones involved. You agree with that? Your heart starts beating, yes, what else did we say, Lauren, about your skin? Are they anywhere near each other in particular?

**Lauren:** No.

**T:** So, you understand that it's happening in different places, yes. So, these glands have target tissues, yes? All over the place.

**T:** There must be a gland somewhere that produces growth hormone for growth to have this effect in your bones and what else needs to grow in your muscles, right?

We don't imagine that there's a gland there, one there and one there. There must be a place where there's one of these glands, yes? So, when it gets to your bones and muscles, it helps them and causes them to grow.

So, I think what would be useful is to list some of these glands and what they actually do, yes? Just like a little two column thing. So, let's have the gland on the left hand side of the column. [ ] You could have two or three column you decide. I can actually have the gland what it produces, what the hormone is called and what that does or I could just have the gland and the hormones and what it does together. So, do just what you want.

**S:** Two or three?

**T:** Well, you choose. You can do it either way. Put the gland on the left and either the hormone and what it does on the right or two columns; hormones and then on the right what it does. You choose.

So, let's do the ones we know. What's the ones we know? [ ] Female, Kim, the female. What are the ones we know already?

**Kim:** Ovaries [ ]

**T:** Ovaries. On the left hand side. It produces two hormones, Oestrogen and Progesterone. What are they to do with, Vickie?

- Vickie:** Releasing the egg.
- T:** Yes. It must have something to do with that. What else? Nothing to do with releasing the egg. What else do you know about ovaries?
- S:** Menstrual cycle.
- T:** Menstrual cycle. What else happens to you during adolescence once you start producing from your ovaries? [] What about the breast, pubic hair. Well, this is what it does, right?
- T:** It regulates, this is the function of it, menstrual cycle [ ] and helps to develop female sexual characteristics.  
(dictating)
- T:** Do you know what I mean by that, (student name)?
- S:** Yes sir.
- T:** We have a name for that, we call those, it's nothing directly to do with the hormones, we call those secondary sexual characteristics. So, the main characteristic is producing an egg and producing the lining. That's the main thing. The big change. It has the other effects as well.
- S:** .....
- T:** No, not directly. You see what I'm saying, secondary. The main thing is that it producing an egg. There are secondary things that happens to you as well. So, we call the other things secondary.
- S:** .....
- T:** Well, it does. In what way?

**S:** .....

**T:** If you didn't develop this breast tissue produce the male, that's a good point, yes. Do you think it makes any difference whether you're sweatier or hairier or your hips are wide?

**S:** (not clear???)

**T:** I wonder, do you think hip widener is just, you know, the hip is like a basin with a hollow, do you think hip widener is just on the outside or somehow the inside's got one?

**S:** The hips widens so that the baby can come through.

**T:** You're saying as someone grows, it widens to make room for the baby to eventually come through.?

**S:** Yes.

**T:** Okay. So, we'll do the male one because we know that one too. The hormone testes.

**T:** The hormone produced is testostomone and that is to do with developing and maintaining the secondary characteristics.(*dictating*)

**T:** So, which hormone do you think it is that female athletes might think of taking? [ ] To develop more body mass symbol.

In fact, which male athlete would think of taking such hormone?

**S:** .....

**T:** What is that one, the one that we talked? Remember we said that there's another time when, you know, that this hormone is probably run down. You can feel this hormone isn't there?



**S:** When you're having your period.

**T:** No. That's to do with your menstrual cycle. There's another time.

**S:** When you're frighten.

**T:** Yes, when you're frighten. You know that sort of like - really - what does the hair on your body do?

**S:** Stand up.

**T:** Yes. What does your breathing goes like?

**S:** Panting.

**T:** Okay, so, that's another gland called adrenal gland.

**S:** .....

**T:** Yes, well done, Layla. Adrenal gland and it produces adrenalin. Everybody does this one. The boys gets this just the same as girls. What is it for? Why would you want your lungs.. why would you want your rib cage to come up here and your diaphram to go down about there and up again? What are you trying to get a lot of?

**S:** Air.

**T:** Particularly oxygen and your heart is just going -boom, boom! What are you trying to get more into your body?

**S:** Blood.

**T:** Lots of blood, which contains?

**S:** Oxygen.

**T:** Oxygen, and?

**S:** Food.

**T:** Food. What does that sound like you're getting ready to do?

**S:** .....

**T:** It sounds as though you're getting ready for something pretty active, yes? For someone like Linford Christie and Sally Gunnell, that might be at the beginning of a race. And for someone like Billy Connolly, it might be the beginning of a concert or something.  
For me it would happen if I leave Uxbridge late one night, perhaps on a Friday or Saturday night going to Slough probably, and it was really late and the car broke down and I had to walk home; seeing these people crawling out of pubs and a bit sort of, you know, like... "Oh! Look that's sir!" Impersuasive.  
These are things that will start to produce adrenalin glands then. Why do you think? Because what do you think I'd be ready to do?

**S:** Run.

**T:** Yes. I'm going to leg it. And what would my blood need? A lot of oxygen and?

**S:** A lot of energy.

**T:** A lot of energy because they're going to be doing a lot of work, yes? What else do you think I'm going to want to be ready good for if I'm going to leg it? [ ]  
So what would have to be very good?

**S:** Eyesight.

**T:** Yes, eyesight. When you're pumping adrenalin, your eyesight gets clearer, believe me, it gets clearer.

**Your ability to see gets clearer. How about your ability to hear?**

**S: Better.**

**T: That gets better as well. Yes it can. Do you think that while this is going on, your body in any way would be interested in digesting a big mac that I ate half an hour ago. Do you think my body would actually ...**

**S: No.**

**T: No. This would be of secondary importance to my body. So, where do you think most of my blood would be going? Which part?**

**S: Muscle.**

**T: My muscle, yes. Very little would be going to your gut because your body would think, "I'll do that another time. Let's get out of this." So, that's a lot of changes. So what does this prepare for?**

**T: Prepares the body for action. (*dictating*)**

**T: There's another gland you might have heard of. It's about here. Have you heard of these ones. Round here, it begins with "T". Have you heard of Thyroid. Some people have heard of it. Thyroid. It produces a hormone called Thyroxine. Do you think, have you heard anyone say that, "All I have to do is look at a cream cake and I put on half a pound."**

**S: Yes.**

**T: Some people have. Have you heard these people say, "I eat like a horse."**

**S: Yes.**

- T:** And, "I never put on an ounce." You know that, don't you? Do you think there are people who's body chemistry, like what's going on inside goes faster than other people?
- S:** Yes.
- T:** So, some people seem to be like slow and other people who don't necessarily do more but their bodies seem to be going faster than other people's. Do you think..
- S:** .....
- T:** If you're lazy, does your blood get thick? Do you think you can have a baby by, a boy or girl?
- S:** The shape of the bump. [ ]
- T:** So are you trying to tell me, think of this little foetus about to be born, has it gone through secondary sexual development? A little baby brother, a penis about this big, you're telling me that that alters the swelling...I'd like to see the paper in nature that established that data! Do you think it's likely that a penis on a little baby boy is going to affect a pregnant mother's bump in any way? Do you think it's likely? I'm not says it's true or not.
- S:** It might.
- T:** You think it might?
- S:** It depends if the woman's having a girl or boy.
- S:** If she's having a boy, she gets heavier and fatter; if it's a girl your stomach gets round.
- T:** Your abdomen. [ ]  
In science, what are we always trying to do if we're faced with a problem or a proposition?

**S:** Test it.

**T:** Yes, test it. Do you think a lot of things people say are accepted but not tested?

**S:** Yes.

**T:** Do you think if people say you're having a boy, you've got a fat bump or whatever?

**S:** I believe it.

**T:** Do you think it's been tested or it's just accepted without being tested?

**S:** Accepted.

**T:** All I'm going to say is that this approach, the scientific approach is to try analysing it as much as possible, I'm not saying science is wonderful and pure, but as much as possible, to try and analyse something and find some evidence for it rather than just accepting. Because, if you go into French and they say the French for table is table then you just accept that. But in science the whole idea is to look at a problem and try to prove it one way or other as much as you can. And, I think there is very little evidence for some of these things, and you get some from old wives tales but there's not much evidence - it's just what I've heard.

We're onto thyroids. You know we talked about different people having different rates of body activity, it's called metabolism, the thyroid affects this. So, write down...

**T** Affects the rate of metabolism. It is a measure of all activities in cells in your body.*(dictating)*

- T:** If we thought there was someone who had an overactive thyroid, if it was producing too much thyroxine, what do you think would be happening to them?
- S:** They'd be ill.
- T:** So, what would doctors try to do?
- S:** Reduce the thyroxine.
- T:** Yes. They would try to reduce it. What about someone who had a serious problem controlling weight? What would the doctors think was possibly going on here?
- S:** Not enough.
- T:** The thyroids not producing enough. So hey would look at that and where would they measure ? Would they be able to measure the gland? What would they sample?
- S:** They'd do a blood test.
- T:** Yes, they would do a blood test because where are these hormones put?
- S:** Into the blood.
- T:** So, all you have to do is sample the blood and see how much thyroxine in it. Let's look at, anybody here a diabetics. Do you know the name of the hormone involved in that? Anybody know you can actually get injections for it? For these hormones, that diabetics have?
- S:** Insulin.
- T:** Insulin. Now, the gland for this is a bit complicated because it's in the pancreas, but produced by something special by a gland within a gland ???, the actual gland is Islets of Langerhans, which are in the pancreas.

**Those Islets of Langerhans are in the pancreas. There in the pancreas. What do they produce, Aisha?**

**Aisha: Insulin.**

**T: Yes, and what does insulin control?**

**S: The sugar.**

**T: It help to regulate the glucose levels in the blood. [ ]  
Does anyone here play a musical instrument?**

**S: Yes.**

**T: Where did you play, at school or in a band.**

**S: Orchestra.**

**T: Anyone else?**

**S: Piano.**

**S: I play the trombone.**

**T: What would happen if you'd all got together as a group of people and you could all play these instruments, and you just start to play?**

**S: You get a racket.**

**T: There would be a racket. In order to control it and to make sure it all works and plays a tune, what do you need?**

**S: A team.**

**T: To work as a team. You need a team. What does an orchestra usually have?**

**S: A conductor.**

- T:** A conductor and what does a conductor do?
- S:** Controls the whole thing.
- T:** Yes, a conductor controls the whole thing. So, think about it. We've said ovaries, testes, adrenal glands, thyroids, Islets of langerhans, if they were all doing their own thing, what would the body be like?
- S:** A catastrophy.
- T:** It would be a bit of a mess. So, you can probably half guess that there is some sort of system controlling all the glands together. Some way of making sure that all switch on and switch off at the right time.  
So, I want you to write down on the right hand side, Pituitary gland. [ ] Now, this thing that controls everything that goes on in the body, all the chemicals that are released, where do you think it is?
- T:** At the base of the brain connected to Hypothalamus controls the release of hormones for the other endocrine glands and also produces its own hormones. [ ] (*dictating*)  
Laura, do you know what PMT is?
- Laura:** Pre-Menstrual Tension.
- T:** So, that's to do with feelings and moods and emotions, changing through the month. Some people get very tense before the period. So, what I want to look at in more detail is the menstrual cycle. The next heading is as a side heading.
- Hormones and the menstrual cycle. [ ]



- T:** First of all it would be a good idea if we knew what the menstrual cycle was. So, let's start with day zero.
- T:** Day zero to day five, the lining of the uterus is shed.  
(*dictating*)
- T:** So, from then, when is the egg released, counting from then, counting from the first day of the your period about when you think the egg would be released next time round. It's a 28 day cycle. When you get to 28, you shed again. So, when do you think within that cycle?
- S:** Three days after.
- T:** Yes, three days after that. It's around about day 14 or day 15, ovum is released. [ ]  
What must have been happening between day 5 up to 10 and day 14/15? What's been happening? Think what just happened to your lining, so what's been happening from 5 to 15?
- T:** Day 5 - 14 new lining begins to grow. When the egg's released. Do you know what happens to the lining when the eggs released. Something happens on its release. The egg is now on its way, it might be fertilised. You've just grown a lining. What do you think you'd want it to be when the egg got there. (*dictating*)
- S:** Full.
- T:** Full. So, say from 15 onwards from 15-18, lining thickens. It gets thicker and if the egg doesn't get fertilised eventually wants going to do as it swings around again after 28 days, the lining's going to disintegrate and then day zero, if the egg hasn't been fertilised, it's going to be shed again. So, you see how the cycle works?  
What two hormones do your ovaries produce?
- S:** Oestrogen.

(The end of lesson bell brought the discussion to an abrupt end.)

## 7.6 Comments on the Transcript and Comparisons with Muslim Schools

We see that the lesson is taught, in the words of the teacher, in ‘an enlightened secular perspective’. There are blunt statements made about anatomical features (‘breasts get bigger, penis enlarges’, for example) that could not be made in the absolutist environment of a Muslim school classroom. Here, even to discuss a topic like Hormones in the context of National Curriculum science requires one to go through a prior process of religious vetting (as the Headteachers and Principals of the Muslim schools I visited informed me). Reproduction (of which the topic hormones is a part) and the National Curriculum cross-curricular theme of Health Education (which includes sex education) must be taught by female teachers to female pupils and by male teachers to male pupils. A strong input from holy scripture (the Quran) and Hadith (sayings of the Prophet Muhammed) is an absolute necessity. These religious resources are used (when teaching this and other science topics) as powerful pieces of metaphysical ammunition, designed to strike at the hearts of impressionable minds.

The ‘enlightened secularist’ science teacher, on the other hand, is teaching his lesson in a highly interactive way, constantly asking diagnostic questions as he ploughs his way through the topic. Recent developments in science (still at an experimental-theoretical stage) are occasionally pointed out - see, for example, p.253 where he points out that scientists have noticed a reduction in male fertility (statistically significant to some) in the west of Britain. There is a danger, here, however, of inadvertently blurring the line between the content of scientific research and lapses into speculation when discussing its possible implications. We are talking of Year 9 pupils after all.

Elsewhere (pp.266-267), in an interesting discussion on the nature of science with a Year 9 pupil, the teacher comments:

**“But in science the whole idea is to look at a problem and try to prove it one way or other as much as you can.”**

Reading between the lines it seems the teacher is saying that science works by defining a problem and then putting forward testable predictions to either prove your case or to refute it. Either way, one cannot arrive at absolute certainty - only approximations to the truth (‘prove it one way or other as much as you can’).

Muslim schools, on the other hand, by equating Quranic verses with the current content of National Curriculum science, tended to reinforce the (in my judgement) erroneous impression that scientific theories in their current state are absolute. Their line of syllogistic reasoning appeared to be as follows:

1. The Quran is the unchanged Word of God and is absolute.
2. Seeds of scientific theories are in the Quran.
3. Hence the scientific theories are absolute.

Muslim science teachers were also reluctant to use the Association for Science Education (ASE) SATIS supplementary material in their lessons. One Muslim teacher, whom I spoke to after observing one of his lessons, commented:

**“The approach adopted in the SATIS units is an amoral and secular approach; the implications of science and technology are not discussed in the context of absolute moral values, as they are in an Islamic education system ... we need to enrich the National Curriculum by providing such input for our pupils.”**

In this context, it is interesting to quote a passage on the connections between teacher moral dimensions and their views on the nature of science (Koulaidis & Ogborn, 1995):

**“The moral dimension associated with teachers’ views of the nature of science ought to be investigated. One reason for this suggestion is the conflict between the notion that there is no special role for science in morality (perhaps an amoral one) and the perception of the scientific community as inherently founded on a moral order (e.g. Harré, 1986). Any such investigation needs to be done with some care. It is important to be able to bring out diversity in teachers’ views. Thus, it should not be taken for granted that teachers’ positions presuppose the merits or moral status of science.” (Koulaidis & Ogborn, 1995, p.281)**

The interaction between scientific and moral perceptions in Muslim science teachers working in Muslim schools has been explored in Chapter 8. In this population, of course, the moral perceptions associated with their views on the nature of science are entirely based on an absolutist religious dimension. We now turn to a detailed discussion of my findings.

## **References**

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## **CHAPTER 8**

### **INTERPRETATION OF FIELDWORK STUDIES**

- 8.1 Central Findings**
- 8.2 Teaching ‘Scientific Method’**
- 8.3 Are Teachers Clear about Scientific Method?**
- 8.4 Making Sense of Observations**
- 8.5 Values in the Classroom**
- 8.6 Changes in the National Curriculum**
- 8.7 Statements of Relevance to Muslim School Science**
- 8.8 Science Teaching in Muslim Schools**
- 8.9 The AMS Science Curriculum**
- 8.10 Establishing Links between Quranic Statements and the National Curriculum**
- 8.11 The Nature of Science in the National Curriculum**
- 8.12 Concluding Remarks**

## **INTERPRETATION OF FIELDWORK STUDIES**

### **8.1 Central Findings**

In Chapter 7, I described how I set up and recorded details of my interviews with 15 Muslim and 5 non-Muslim science teachers. The interviews were designed to add further light to views about the nature of science the subjects had expressed when responding to the Koulaidis-Ogborn philosophy of science questionnaire. Some transcripts of these interviews were reproduced in Chapter 7. A description of my 5 subsequent lesson observations were also given, with a commentary on some of the key differences observed between science teaching in an Islamic-oriented Muslim school and a secular-oriented state school.

The differences between Muslim teachers in my sample in their perceptions of science were not sufficiently clear to merit categorisation in an absolute sense. The database analysis of questionnaire responses paints a similar picture in the case of non-Muslim teachers (see Chapter 6, section 5) where I have shown, with clear examples from my research, the serious difficulties involved in attempting a categorisation. Adherence to a religious faith (Muslim or Christian) in no way implied concomitant predilection for a particular mode of metaphysical-philosophical framework, be it broadly inductive, conjectural-inductive, hypothetico-deductive or contextual. As Koulaidis and Ogborn have recently said in connection with their work with PGCE science students:

“The picture we have drawn suggests rather strongly that future research in this area should avoid investigations assuming that teachers have one or other completely consistent view of the nature of science. The evidence suggests that they hold eclectic or mixed views, adhering to a diversity of elements taken from different philosophical positions. Therefore, the role of philosophical analyses of science, for such research, is not to provide ready-made total positions for teachers to be slotted into, but rather to construct a collection of elements,

i.e. positions on different philosophical themes, which can be used to analyse and represent teachers' thinking." (Koulaidis & Ogborn, 1995)

In conversation with Muslim science teachers, after observing one of their lessons, it became apparent that the teaching of science was driven by the principle of glorifying the Creator. In one sense, the science was taken as read, in that the focus of science teachers was not to explore how scientific knowledge was gained or to question its validity but to display the authority of the Quran and its predictive power. As one respondent commented:

*'Religious statements in the Quran are quite revealing - scientifically. Revelation transcends religious knowledge - it is of great validity ... we should use the Quran to judge scientific theories and to create new ones.'*

For instance, Allah says in the Quran:

*"soon will We show them Our Signs in the (furthest) regions (of the earth), and in their own souls, until it becomes manifest to them that this is the Truth". (41:53)*

The theory-ladenness of observation statements or the hypothesis-led constructivist approach of alternative frameworks, were apparently secondary matters to this theological aim. In general, of course, Muslim teachers appeared to be oblivious of such philosophy of science concepts, stressing the importance of searching for the 'Signs' of God in nature without worrying about the context of scientific discovery or indeed its justification. The 'signs' are present everywhere in the universe; Muslim scientists have to search for them by engaging themselves in a profound study of the Quran.

The Principal of one of the Muslim schools (a scientist) said that:

*'As human beings we are limited by our senses, through which we hear, see and touch and generally receive information, and by our minds with which we think. But acquiring information in this way (the basis of scientific investigation) does not mean that we are 'good' people - indeed we could be evil and our senses will testify against this: "And do not follow anything of which thou hast no knowledge:*



*verily (thy) hearing and sight and heart - all of them - will be called to account for it (on Judgement Day)!" (Quran, 17:36)'*

This verse was the justification for not pursuing ethically questionable scientific research or, indeed, incorporating it in science education curricula. Some scientific discoveries were viewed as signs of God's omnipotence and omniscience - they should strengthen one's beliefs rather than detracting from them. As one teacher summed it up:

*'Scientific knowledge should lead Muslim children to recognise the truth. This is indicated in the Quran when Allah says "Now those who are endowed with knowledge are well aware that whatever has been bestowed upon thee from on high by thy Sustainer is indeed the truth, and that it guides onto the way that leads to the Almighty, the One to whom all praise is due." (Quran, 34:6)*

Some general points can now be made. Science teaching schemes (of general use in state schools) which have been developed over the last two or three decades have had a definite impact on science teachers' (generally hazy) perceptions of the nature of science. Science is rejected as a catalogue of facts and presented as a coherent system of ideas. Emphasis is placed on the integrating concepts or big ideas such as atomic theory in chemistry or kinetic theory in physics. In making connections between these ideas and statements in the Quran, Muslim teachers overlooked the proposition that the connections apparent to a Muslim science teacher may be far from obvious to a pupil. Little attention was paid to the ideas the children themselves brought to the lesson; establishing the faith-science link was the purely didactic part. In the lessons observed, Muslim science teachers tended to direct the pupils towards a predetermined transcendental aim - recognition of and glorification of the Creator - rather than attempting to evoke responses from the pupils based upon their own personal experience. An awareness or regard for constructivist/alternative framework dimensions was therefore lacking. One is reminded of David Ausubel's comment on the importance of considering what he called children's preconceptions, suggesting that they are 'amazingly tenacious and resistant to extinction'.

*'My views about science are underpinned by my religious faith. I try to impart these views to my students as much as I can. There are areas in the syllabus which lend themselves to such analysis - especially the astronomy part where we can relate science and religion.'* (a Muslim school science teacher)

I make now some general points arising out of my findings. Regardless of teacher religious background, the situation pertaining in state schools was that 'processes' were seen as a major part of what is to be taught. (This came out through post-classroom observation questioning and perusal of resources used for preparing science lessons). This is not surprising when you consider that Science in Process (ILEA, 1987), for instance, talks of the 'acquisition and use of process skills' and of processes being 'taught'. Nuffield 11-13 speaks of 'the skills to be developed' (Nuffield, 1986). Warwick Process Science argues that 'a knowledge-led curriculum has little relevance' because of the explosion in information and the ease with which it can now be accessed (Screen, 1986). In short, the aim is to develop scientific processes through teaching.

Rather than one universal ahistorical methodology, most teachers portrayed the method of science in terms of discrete processes thereby defying crude categorisation. As one science teacher commented:

*'I think a number of methods can be adopted in science; it depends on the style of the person doing science.'*

This relates back to the difficulties I experienced in attempting to categorise all my Muslim and non-Muslim respondents into predetermined philosophical categories based on the four Koulaidis-Ogborn philosophy of science profiles of scientific method, criteria of demarcation, patterns of scientific change and status of scientific knowledge (Koulaidis & Ogborn, 1989). There I found that such a clear-cut division was not possible, no identifiable patterns emerging in the differences in responses between Muslim and non-Muslim science teachers - or, indeed, between Muslim science teachers teaching in Muslim schools and those teaching in state schools. No

general position (inductivist, hypothetico-deductivist, contextualist, etc) could be sustained all the way through. The eclectic nature of practically all responses coupled with some uncertainties (not responding to an item) and contradictions (holding two mutually exclusive views on an item) indicated a lack of awareness of nature of science issues rather than positions held with intellectual conviction. Subsequent interviewing served to reinforce my initial impressions.

This situation was revealed particularly when interviewing teachers about methods in science and discussing the nature of the resource materials they use in the classroom and employ in making lesson plans. Teachers were reluctant to concede that many of the so-called processes have no special association with science but are common to systematic thought in all formal disciplines, and, indeed, to informal common-sense reasoning, e.g. hypothesis formulation, and making inferences and predictions. Muslim teachers using science for the glorification of God nevertheless wished to elevate its intellectual status amongst formal disciplines by attributing scientific methodology to the Quran. For instance, one respondent commented:

*'I don't think science is biased; it is neutral. Seeds of scientific theories are absolutely in the Quran. Things are discussed in the Quran which have only been discovered recently; for example AIDS - a whole tribe was taken away from the earth because of this disease'.*

This is an example of what I shall call 'explanatory overstretch'. AIDS is not mentioned in the Quran; neither for that matter is the 'big bang' theory of creation or quantum mechanics. Over-zealous Muslim science teachers, however, will go to great lengths in 'torturing' Quranic verses in order to make them conform with scientific theories in vogue and the development of new medical conditions. In this particular instance, reference was made to the following Quranic verse (used in Islamic Health Education classes); 'explanatory overstretch' shows how it can be made to apply to AIDS:

*"We (Allah) also (sent) Lut: He said to his people: "Do ye commit lewdness such as no people in creation (ever) committed before you? For ye practise your lusts on men in preference to women: ye are indeed a people transgressing beyond bounds."*

*"..... And We (Allah) rained down on them a shower (of brimstone): then see what was the end of those who indulged in sin and crime!" (7: 80-84)*

## 8.2 Teaching 'Scientific Method'

Most teachers (regardless of religious background) in the sample were influenced by the DFE emphasis on science as process which stresses the 'methods' of science. The National Curriculum attempts to outline this 'method' as a series of steps beginning with observation, leading via classification to the drawing of inferences and the formulation of hypotheses ('seeking patterns'), and culminating in experimental testing.

This view of science method as a set of discrete 'processes' underpins several recent curriculum packages heavily drawn upon by the science departments of the teachers interviewed. For instance, the Introduction to Warwick Process Science (Screen 1986) lists the processes made 'explicit' in the course as: observing, inferring, classifying, predicting, controlling variables, and hypothesising. Science in Process (ILEA, 1987) draws attention to the following 'process skills': applying, interpreting, classifying, investigating, evaluating, observing, experimenting, predicting, hypothesising, raising questions, and inferring. Nuffield 11-13 (1986) distinguishes 'processes' and 'skills', listing as skills to be developed: handling equipment, observing, patterning, communicating, designing investigations and experiments, and mental modelling. 'Patterning' is elaborated in the Nuffield Teachers' Guide to include classifying and predicting; 'designing investigations' incorporates raising questions, hypothesising and controlling variables. One Head of Science whom I interviewed commented:

*'I think there is one basic scientific method made up of a number of separate processes linked together. The method can be adjusted to suit different situations that crop up. For example, accidental discoveries are occasionally made in*

*science - penicillin and the artificial sugar aspartame, for instance. The discovery (by accident) is made first and then the sequence of scientific procedures for testing dose limits, toxicity, allergic responses, etc, is carried out. In the search for fundamental particles, however, hypothesis and mathematical constructions are formulated first; discovery occurs later (if at all).'*

### 8.3 Are Teachers Clear about Scientific Method?

Current views about scientific processes, including those cited above, present an image of the method of science as a hierarchy of processes, beginning with observing and leading on via classification to inference and hypothesis. This is essentially an inductive view. Criticisms of induction as an account of how scientific inquiry proceeds are commonplace in the literature of philosophy of science (Popper, 1959; Hempel, 1966; Chalmers, 1982 - some of which were discussed in Chapters 1 and 2). In an educational context, the discovery learning approach, which appears to be modelled on the inductive view of science, has also become largely discredited. Some teachers admired this approach, even though the practical difficulties which it poses for the teacher, as students fail to 'discover' what was intended, have been extensively documented (Atkinson and Delamont, 1977; Solomon, 1980; Harris and Taylor, 1983). Impressions were given in some interview responses that knowledge in the form of useful generalisations could emerge from objective and detailed observation. For instance,

*'scientific statements would be based on observations which would be followed up by experiments. Where the experiments seem to back the proposed theory, the scientific statement would be valid.'*

When quizzed about why observations were made in the first place an unsatisfactory response was given by teachers. For example:

*"Without observations you cannot proceed to the next stage in science - theory construction."*

When pressed to elaborate, the teacher explained that scientific method was based on a set of discrete processes and any orthodox scientist would follow these processes sequentially, beginning with observation.

Other interviewees remained agnostic about the origin of hypotheses and generalisations and instead identified the scientific method with the testing of these hypotheses by experiment. This position related to the hypothetico-deductive view of science (also discussed in Chapter 1). As an account of science, it too has been found to need much development and qualification. There is little support from philosophers or historians of science, for example, for the idea that a hypothesis is ever conclusively falsified by an experiment. Some argue that the current hypothesis is never rejected until an alternative is available (Lakatos, 1970), then a 'crucial experiment' can decide between the two. Even this is poorly supported by the historical record. Theory choice seems less like following rules of procedure than the exercise of skilled judgement, frequently influenced by other interests and commitments. As some teachers appeared to appreciate, in the classroom, the hypothetico-deductive approach also has its problems, for instance, both teachers and students faced with ambiguous experimental results from 'difficult' experiments tend to rely on the 'second-hand' authority of the textbooks rather than the 'first-hand authority' of the experiment (Millar, 1987). The nature and sophistication of classroom experimentation and equipment means that established theory cannot be seriously tested in the science classroom.

Amongst historians, philosophers and sociologists of science, then, there is no general agreement about whether science has a method or, if so, what it is. Teachers' perceptions about the nature of science are bound to reflect this; hence the difficulties involved in attempting a categorisation of teachers' responses. Admittedly, though, a crude form of categorisation can be achieved if one allows overlap and placement of statements in several categories. This was the

Ogborn-Koulaidis finding when they used the model adopted in this thesis to work on a captive population of final term PGCE science students.

What one is able to say, however, is that within this uncertainty there is substantial agreement on several points. Most accounts agree, for instance, that scientific inquiry cannot be portrayed as rule following but involves the exercise of skill: in deciding what to observe, in selecting which observations to pay attention to, in interpreting and drawing inference, in drawing conclusions from experimental data, even in replicating experiments. Decisions about all these sets of things cannot be pinned down by sets of rules. Much of scientists' knowledge of the method (or methods) they follow is tacit; doing science is like practising a craft (Polanyi, 1958; Ravetz, 1971). This, of course, has implications for the way science and scientific inquiry are taught.

Scientists do, of course, observe, draw inferences, propose hypotheses, and devise experiments. The point, however, is that these are not necessarily linked by a set of rules and procedures into a method which will guide scientists as to how to tackle a new problem or how to reach agreement on what a set of experimental results mean. Both teachers' responses to the questionnaire and at the interview, and the resources they consulted gave the impression that these 'processes' have a special link with science rather than being, simply, convenient labels for the general approaches which we all use at some time in making sense of the world. It is not just that the method of science is more than the sum of these parts but perhaps that the essence of what it means to 'do science' lies elsewhere. As one respondent said,

*'scientific method is a sequence of processes - observing, hypothesising, testing and predicting',*

suggesting that the National Curriculum sequential model of discrete processes has been successfully adopted by many science teachers. Fundamental questions about demarcation of territory glare at

us whenever we attempt a crude sequential operation in defining scientific method, for these are processes also shared with other formal disciplines and abstract thought. The teachers interviewed had appeared not to have thought this through or, indeed, felt the need to.

Processes such as observing, classifying, inferring and hypothesising are difficult to teach as content-independent strategies and activities. Many resources have designed classroom activities which are supposed to result in students becoming better at the performance of tasks involving these processes which are different from the context in which they were originally taught. This claim of transferability is implicit in the literature on science process, as it was in the response of interviewed teachers across the religious board. If we claim to teach observing, or classifying, or hypothesising, perhaps we are claiming that we can teach students to become better at these, to perform better in tasks which involve these processes but which are quite different in content and context from those we used for instructing them.

Teachers interviewed had very little idea about progression in these 'processes'. For instance, how is one task an 'easy' observing or hypothesising task, while another is 'harder' or 'more advanced'. What is 'elementary' classifying as opposed to 'advanced' classifying - independently of content? It appears that the institutionalisation of 'process science' is a reaction against the content-dominated transmission model of science teaching.

I found, in fact, that it was science teachers in Muslim schools who did not view active learning approaches as the ends or goals of instruction, but as means of engaging students' attention and interest in science lessons. Their goal, of course, was to use the process science approach for fulfilling teleological ends in their science teaching. As one Muslim teacher remarked,



*'The Quran contains the seeds of scientific theories - those known and those yet to be discovered.'*

The evidence for this goal, according to the Muslim science teachers, was the Quran:

*"Soon will We (Allah) show them Our Signs in the (furthest) regions (of the Earth) and in their own souls, until it becomes manifest to them that this is the Truth. Is it not enough that thy Lord doth witness all things?" (41: 53)*

The image of science which the 'process' approach presents is a seriously misleading one when it comes to understanding social issues and controversies which involve science. The process approach subtly shifts the emphasis from science as reliable knowledge towards scientists as reliable knowers. The outcome, I believe, is to encourage learners to invest authority in the scientist, whose knowledge is derived by following agreed rules. Within such a perspective, the only way to interpret disagreements between scientific 'experts' about nuclear power, radiation risk, environmental issues, food additives, and so on, is as evidence either of bias or of incompetence (Millar and Wynne, 1988). (This was brought out in the video-taped lesson on 'Hormones', where the teacher discusses STS issues in a secular, non-didactic and non-dogmatic framework (see Chapter 7, section 5). It is conceivable that a less rule-bound view of scientific and technological practices, where data and results are always open to negotiation before the community accepts them as 'facts', provides a more adequate basis for interpreting the science-society relationship.

Science education is, I suggest, now plagued with an unhelpful and distorting emphasis on 'process'. The teachers interviewed were unable to make any separation between specific skills which can be taught and improved (and may therefore be assessed) and more general processes which cannot. For example, "In science education, skills and processes ought to be taught and assessed". The words are used interchangeably and appear not to have been thought through.

If we use the language of general processes , we need to become clear that it is 'scientific observing' (rather than 'observing'), 'scientific hypothesising' (rather than 'hypothesising') and so on, that we should be aiming to develop and promote through school science, and recognise that the exercise and development of these skills depend crucially on a basis of science content and concept knowledge.

Science National Curriculum rhetoric, which influences teacher perceptions though not to an extent allowing simple categorisation, propounds a view of scientific inquiry at odds with current scientific thinking. Amongst philosophers and sociologists of science it is now generally taken for granted that scientific inquiry cannot be seen as a set of rules or standard procedures which can be applied unproblematically to all situations and which can provide simple and direct means of acquiring new knowledge or of confirming proposed explanations. Science does have characteristic ways of working and characteristic standards of judgement and appraisal, all of which are governed by current conceptions in the field of study as well as by available technologies and are influenced by the purposes for which the inquiry is undertaken. These can never, however, be encapsulated in a set of rules. They contain many tacit elements which can be communicated only through the interaction between the learner and a more experienced practitioner. Doing science is more like the skilful exercise of a repertoire of 'craft skills' (Polanyi, 1958; Ravetz, 1971) than the following of an algorithm. The training of scientists involves the process of coming to internalise these tacit canons of procedure and judgement. These points were lost on the teacher interviewees, one of whom commented,

*'I would like to think that there is such a thing as absolute certainty about science. But it is not reasonable for us to assume we know everything.'*

When quizzed about what she meant by ‘absolute certainty’ the Muslim science teacher explained that scientific discoveries are a manifestation of God’s signs in the physical and biological universe. The signs must be true and perfect as God Himself is true and perfect.

#### 8.4 Making Sense of Observations

Though there is a need for caution in talking of a ‘method of science’, there can be little doubt that scientists do observe, draw inferences, propose hypotheses, devise experiments. The point, however, as some interviewees suggested, is that these are not linked by a set of rules and procedures into a method which will guide scientists as to how to tackle a new problem or how to reach agreement on what a set of experimental results mean. One science teacher whom I interviewed said,

*‘Scientists do not have a standard list of rules to follow when conducting experiments. They also differ between themselves in their interpretation of the same experimental results.’*

Perhaps these ‘processes’ have no special link with science but are simply convenient labels for the general approaches which we all use all the time in making sense of the world. Take observation for instance. There is a certain peculiarity in suggesting that it is something we need to be taught. Of course what is meant is that pupils should be taught in science lessons to observe closely, to notice detail, to make relevant observations. But what is relevant? Without a hypothesis or some kind of prior expectation there is no means of deciding what is, or is not, relevant to observe. This is part of what is meant by the now generally accepted view that all observation is theory-laden. Any statement reporting an observation carries, concealed within it, theoretical ideas. In one class experiment I observed in a Muslim school, for example, two girl pupils were investigating the cooling of water in two flasks, one surrounded by insulating material, the other not. The water in both flasks started off at the same temperature. After 10 minutes, they measured the temperature in the flasks and reported: the water was warmer in the lagged flask than in the unlagged one.

Was this an observation or an inference, I asked myself? Perhaps we treat it as an observation, hoping to press on to the inference that insulation slows down energy losses from hot objects. But the girls' report could be classed as an inference, based on the observation: the temperature reading on the thermometer in one flask is higher than in the other. This in turn is also an inference, based on some observation such as the mercury thread inside the glass tube in one of these instruments is longer than the thread inside the other. We are in a situation of potentially infinite regress. We cannot say anything useful about the experiment except by making statements which contain theoretical ideas, and are therefore to some extent inferences.

The same is true of all our experiments. Norris (1984) makes a point in discussing a textbook exercise inviting pupils to write down their observations while watching a candle burn. He argues that it is rational to regard the statement that there is liquid wax (and not just liquid) on top of the candle as an observation, rather than an inference. He argues that scientists typically make the strongest claim which is not subject to reason to doubt and that the mere fact that it is **possible** to doubt that the liquid is paraffin is not sufficient **reason** to have such doubt. It is possible to doubt anything (Norris, 1984).

To follow rigorously a policy of scepticism, then, is not to do good science. Absolute belief in an omnipotent God is the certainty with which Muslim schools begin their science - their way of avoiding the situation of a potentially infinite regress. Gaining scientific knowledge, in this world-view, is more like building an edifice of ideas on best guesses and hunches, which can be tested for their usefulness in explaining and predicting. This is skilful work, not rule following; and this is the message about science Muslim schools may wish to give to their pupils.

## 8.5 Values in the Classroom

In the Muslim faith, the quintessence of knowledge is the pure, unadulterated knowledge of divine revelation. A comprehensive moral and ethical system is constructed on this metaphysical foundation. Knowledge and values are hence inextricably linked (as extensively

discussed in Chapters 1 and 2) and, in this context, Muslim science teachers ought to be highly proficient in introducing, discussing and debating values in the classroom. (The current national concern for moral values in the classroom, resulting in the establishment by the School Curriculum and Assessment Authority in January 1996 of the Forum for Values in Education and the Community, ought to work in favour of a religiously inspired, humanitarian science education.)

There are numerous studies on how STS (science, technology, society) issues should be approached in the classroom, along with recommendations for its promotion. No such guidelines or professional studies exist on how Muslim teachers in Muslim schools should be incorporating STS issues within their theological framework.

Joan Solomon (1992), admitting that STS is too elusive to define, suggests that special STS features within science education include:

- An understanding of the environmental threats, including global ones, to the quality of life.
- The economic and industrial aspects of technology.
- Some understanding of the fallible nature of science.
- Discussion of personal opinion and values, as well as democratic action.
- A multi-cultural dimension.

So what is the teacher's role during such discussions? As Solomon says:

“She or he could no longer direct the discussion towards the uniquely correct denouement but it did seem important, in the melee of different value positions, that the teachers did not try to intrude their own values. In such personal matters there should be absolutely no indoctrination. Out of this debate was born the notion of the ‘neutral chairman’ (Stenhouse, 1969). The teachers could certainly run these new types of discussion, but they should take care to give no inkling of where their own opinions lay.” (Solomon, 1992, p.19)

Following the recommendation of the neutral chair - in practical terms - proved to be difficult. The implicit message was that students should become concerned citizens, and yet teachers were expected to assume an inconsistent and embarrassing position of neutrality. These inadequacies in approach led to the concept of the 'balanced chairperson', closely followed by the 'Devil's advocate'. In the taped lesson on 'Hormones' (Chapter 7, section 5), it is the former strategy that is adopted by the teacher. The teacher helps those on either side of the debate to come to an understanding of mutual positions; there is no overwhelmingly forceful presentation of opinion amounting to what could be classed as subconscious indoctrination, though this may (I dare say), occur in some STS classes, as it occurs in some parts of the science lessons in Muslim schools.

## 8.6 Changes in the National Curriculum

The National Curriculum (NC) has undergone considerable changes since the History of Scientific Ideas component of the Programmes of Study declared:

“Pupils should be given opportunities to develop their knowledge and understanding of the ways in which scientific ideas change through time and how the nature of these ideas and the use to which they are put are affected by the social, moral, spiritual and cultural contexts in which they are developed; in doing so they should begin to recognise that, while science is an important way of thinking about experience, it is not the only way.” (Science for ages 5 to 16 (1991); Proposals of the Secretary of State for Education and Science and the Secretary of State for Wales, DES May 1991, p.44).

This preamble to AT17, so beloved of Muslim schools, has been fragmented and reintroduced in a diluted form through the application of science and nature of scientific ideas components of the new (post-Dearing) programmes of study.

Bereft of a metaphysical outlook (moral, spiritual and cultural context of scientific theories), a more mundane contextualisation is endorsed through the teaching of the four new attainment targets:

Sc1: Experimental and Investigative Science

Sc2: Life Processes and Living Things

Sc3: Materials and their Properties

Sc4: Physical Processes.

John Bausor's critique of this impoverished outlook (with which I agree) was discussed earlier (Chapter 4, section 6), where he cogently argues that National Curriculum emphasis on "social and historical contexts" inevitably means the marginalisation of "cultural, spiritual and moral" contexts to science education. This is a great drawback for Muslim schools also, who consistently remind their students (with a touch of nostalgia) of the Golden Age of Muslim civilisation with their attendant historical contributions to the development of science. Moral and spiritual guidance from the Quran is said to have been used by the Muslim scientists practising their science. In other words, the National Curriculum 'sin' of omission (of cultural, moral and spiritual contexts to science) impoverishes a science education which explicitly refers to social and historical contexts only. Again, John Bausor's analysis as Secretary of CISE (Christians in Science Education) is most perceptive.

The National Curriculum retains, nevertheless, statements of relevance to Muslim school science.

## 8.7 Statements of Relevance to Muslim School Science

(from KS4 programmes of study, DFEE, 1996)

Applications of science theme. Pupils should be given opportunities to:

consider ways in which science is applied and used, and to evaluate the benefits and drawbacks of scientific and technological developments for individuals, communities and environments; and to consider the power and limitations of science in addressing industrial, social and environmental issues and some of the ethical dilemmas involved.

The nature of scientific ideas theme. Pupils should be given opportunities to:

consider ways in which scientific ideas may be affected by the social and historical contexts in which they develop, and how these contexts may affect whether or not the ideas are accepted; and to relate social and historical contexts to scientific ideas by studying how at least one scientific idea has changed over time (KS3 POS statement The nature of scientific ideas).

Muslim science departments are trying to get hold of materials which show that the theories and ideas of Muslim scientists were the direct precursors of developments, centuries later, of western science. This view presupposes a linearity in scientific thought regardless of the social and cultural milieu of the historical Muslim and, more recent, western scientist. In fact, a recent Islamic exhibition for secondary schools at the Ealing Education Centre developed this theme specifically in the science section. It has a powerful appeal to Muslim science teachers teaching in Muslim schools.

In this exhibition (which, incidentally, was repeated in many other parts of Britain) the empirical side of science in Islam is emphasised. Al-Haytham's introduction (eleventh century) of a new mathematical and experimental approach to the study of vision and light is described,



his book on Optics probably being the most influential treatise on the subject until Newton's own book of the same title was published 700 years later.

Stress is also laid in the exhibition on Copernicus's great ~~debt~~ to his Arab (Muslim) predecessors as he used the same graphical device, called a Tusi couple, to calculate planetary motions that had been developed by the astronomers of the Maragha observatory in western Iran (established by the thirteenth-century Mongol ruler Huiagu Khan). The aim is not to belittle western scientists but to locate them in their proper context as part of a great international community of scientists and thinkers whose uninhibited sharing of knowledge made it possible for science to advance rather than stagnate.

The transmission of Islamic science to the Latin West was an organic process. Like all organic processes, things undergo changes, modifications, and reinterpretations in the course of transmission. Just as the Islamic world did not absorb wholesale the entire body of Greek knowledge, so Western Christendom did not assimilate all of the Islamic intellectual heritage. And just as Islam integrated into its own cultural matrix whatever it took from the Greeks, so did the West creatively make part of its own framework whatever it brought from the world of Islam. Transmission of knowledge, then, is not a passive reception of the output of one cultural milieu in that of another.

It is important to appreciate this view of transmission of knowledge as it saves us from a common scholarly disease in the Muslim scientific community which has been aptly dubbed as "precursitis". This is the disease of reading the scientific achievements of the present into those of the past - a pastime current Muslim science teachers found too tempting to resist. Claiming, for example, that Ibn Shatir is the precursor of Copernicus (Ibn Shatir, the 14th century Damascene astronomer, had made a decisive use of the Tusi couple but he was still working in

the geocentric system of Ptolemy); or that Ibn Nafis is the precursor of William Harvey (Ibn Nafis, d.1288). He knew what is called the “lesser circulation” of Hood, but he definitely did not know the “systemic circulation” which was discovered by Harvey (d.1657); or that Muslims knew about the Law of Universal Gravitation before Newton did; or that the knowledge of infinitesimal calculus existed in the Islamic world before Leibnitz invented it in the 17th century. Such claims, frequently expressed by Muslim science teachers and taught to students in Muslim schools, seem to betray both an inferiority complex and an ignorance of the intricate web of historical, philosophical, and cultural factors that determine the course and the contents of the scientific enterprise.

#### **8.8 Science Teaching in Muslim Schools**

Two Muslim schools , both in Brent, London, have been developing a secondary science curriculum that integrates Islamic teachings with the requirements of the National Curriculum.

The old AT17 The Nature of Science, was a godsend for such schools who are now reluctant to operate outside its parameters. Supplementary science materials were developed with Islamic input with the aim of fulfilling the cultural differentiation statements in the science orders and ethical parameters in the NC cross-curricular theme of Health Education.

In fact, the present writer was taken on as a consultant by Muslim educational groups to develop a framework in which to produce such materials. Though technically out of date (as a consequence of progressively truncating the science attainment targets and programmes of study), my initial efforts are still used by the secondary Muslim institutions mentioned above. The framework I developed is presented in the Appendix, but the science curriculum objectives of the Association of Muslim Schools (AMS) are reproduced below.

One of the major methodological problems is that of the Quranological world-view which is now manifesting itself powerfully in the science departments of Muslim schools in Britain (of which there are currently 25, all privately funded and struggling financially). A distinct world-view is promoted: that of discovering the seeds of new scientific theories in the Quran. Anything that has the potential of being discovered must be found in some form in the Quran. The Quran should be the starting point for Muslim scientists and Muslim students of science - a view inculcated through NC science teaching in the laboratories of Muslim schools. (Please refer to the video-taped lesson submitted with this thesis, where the teachers begin science lessons with quotes from the Quran which supposedly relate National Curriculum science to revealed verses.) This, in my judgement, is a one-dimensional prescription which is likely to generate students who may find it depressingly difficult to engage in a rigorous debate pertaining to theory construction and application. If one religious document revealed 1400 years ago is to be consulted in the hope of discovering or generating a new scientific theory then numerous other doors to discovery become closed or permanently inaccessible. Such a parochial perspective needs challenging (as it was in Chapters 1 and 2) and it constitutes a grave problem for science teaching in Muslim schools.

## 8.9 The Association of Muslim Schools Science Curriculum

The 25 Muslim schools in the UK are all affiliated to an umbrella body, the Association of Muslim Schools (AMS). There is, at the moment, no formal document on implementing their pedagogy of science teaching by directly linking National Curriculum statements with Quranic verses. The AMS has, however, produced a brief introductory document on secondary science education which is reproduced below.

**(a) Knowledge, science and revelation**

The Messenger, upon whom be peace, told us that ‘seeking knowledge is a compulsion on every Muslim’. Although there is disagreement about what constitutes compulsory knowledge, there is a general consensus that it is not limited purely to the study of Quran, *hadith*, etc. Knowledge falls into two categories. That which is acquired through revelation and that which is acquired through experimentation. Some have misunderstood this distinction to imply a ‘secular’ view of knowledge. This is supported by certain inaccurate translations of works like Ghazali’s *Ihya Ulum al-Deen* which wrongly suggest he divides knowledge into the ‘sacred’ and the ‘profane’. It assumes that Islam has gone through the crisis described, by Maritain (1966), that Western Christian culture and civilisation went through during the seventeenth, eighteenth and nineteenth centuries. The result of such crisis was that, not only were religion and science seen as incompatible, but, that the development of a society was dependent on it ‘evolving’ from its ‘primitive’ roots to adapt to ‘the modern world’. Progress was the transition from ‘theology’ to ‘science’. This idea, which developed in the early nineteenth century with philosophers like Comte and led to Nietzsche’s assertion that ‘God is dead’ is what informs much of modern scientific thought and therefore curriculum planning.

Science is the quest for truth through investigation. The study of Religion is finding The Truth through His words. There should be no contradiction.

**(b) The Role of Science in Islam**

The Quran calls people to look around them and investigate. It calls them to contemplate the greatness of the creation and consider how perfect it is. It asks:

*'Do they not look at the camels, how they are made?*

*And at the sky, how it is raised?*

*And at the mountains, how they are fixed firm?*

*And at the earth, how it is spread out?' (al-Ghashiah 88:17-20)*

On numerous occasions Allah tells us to look at the creation and then tells us:

*'Thus doth God make clear His signs to you: in order that you may understand.'* (Al-Baqarah 2: 242).

Faith is based on examination of the world around us and consideration of its beauty, order and sophistication. Those who believe in a Creator draw the conclusion that this world must have been fashioned and patterned by a Great and Powerful Creator.

Scientific discoveries start from the same point, but, do not always lead the discoverers to the same conclusion. Archimedes discovered his 'law of displacement' while contemplating in the bath and Newton's laws of motion developed from his observation of an apple falling from a tree. Science and Religion should not be in conflict.

The development of a child's thinking is not only dependent on observation but also on guidance from the teacher. If the teacher has Certainty (*yaqin*) about the Creator, he or she should be able to explain the 'signs' and help the child gain an 'understanding' according to the Quran. This is the difference between science in a secular school and the approach in a Muslim school. Science in Islamia starts from a point of certainty (guidance of the Quran), not of doubt.

### (c) **Science and the National Curriculum**

The British National Curriculum has undergone many changes since its introduction in 1988. The science curriculum originally had seventeen attainment targets which has now been reduced to four. Since 1991, Islamia school had reorganised the original seventeen targets to suit its timetable and the expertise in the school. During the years that followed, the levels of achievement were under constant review and adjustment to make sure that they were in line with the original aims of the school. The school now has more curriculum areas than the four attainment targets set out in the statutory programmes of study. Their arrangement is according to year groups and include statements of attainment in line with the approach described above and our general aims agreed between the Muslim schools. Each curriculum area has its own objectives.

### (d) **Aim of Teaching Science**

The aim of teaching science is to help young Muslims to gain wisdom and the skills and abilities to observe, investigate and discover the secrets and meanings of Allah's chosen role for humankind which is as His *khalifah*, vice-regent on earth. We must show them how they can use the world around us for the benefit of the human race and the animal world. They should always be aware that their actions will be taken into account on The Day of Judgement.

### 8.10 Establishing Links between Quranic Statements and the National Curriculum

“Science is the quest for truth through investigation. The study of Religion is finding The Truth through His words. There should be no contradiction.”

(From the Science Curriculum document for Muslim schools quoted in full length above.) The signs of God are taken in a teleological way as certainty of His existence, but what is problematic is the subsequent claim that science therefore starts from a position of certainty not doubt. Certainty is about the omnipotence and omniscience of God and the guidance of the Quran.

In the field of science education, then, science would be taught as though it were absolute and incontrovertible knowledge. What are believed to be scientific facts tying up with Quranic statements are taught in this way. For instance, the taped lesson on the universe (Y.7) clearly shows the teacher attempting to make a watertight linkage between planetary motion and Quranic verses.

“He who has created seven heavens in full harmony with one another; no fault then wilt thou see in the most Gracious Lord’s creation. And turn the vision (upon it) again: can’t thou see any flaw? Yes, observe it twice again and (every time) thy vision will fall back upon thee dazzled and defeated.” (Chapter Al-Mulk, verses 3-9).

Such verses are invitations to ponder, reflect, and investigate the orderliness prevailing in the universe. In my judgement, however, they cannot be used as evidence to claim that science in Islam begins from a position of certainty. The only certainty is the existence of an omnipotent, omniscient and omnibenevolent Creator, but this is a certainty of faith. There would be no place for critical evaluation of laboratory results if learning always began from a position of certainty. Indeed, it is not a very meaningful proposition, there being an obvious confusion between a belief system based on inherited dogma (in the form of explicit moral guidelines), and scientific practice (based on approximations to truth).

Other taped lessons of Muslim science teachers in classrooms have shown a clean break between that part of the science lesson where NC-Quranic linkage is attempted and a subsequent practical session. The latter is entirely based on NC programmes of study, fulfilling Sc1 criteria in the context of Sc2, 3, or 4. for instance, in one taped lesson discussion of Quranic verses pertaining to natural phenomena was followed by an investigation where no such connections could be made. Marble chips of known mass were reacted with measured volumes and known concentrations of hydrochloric acid in a conical flask, and the loss in mass of the contents

investigated. This could have been a practical session in any other secular school, fulfilling the requirements of Sc1 in the context of Sc3. Replacing 'nature' with Allah in science textbooks may provide a psychological balm for the Muslim science teachers' inferiority complex but it does not solve any real problems.

The claim is made (as we saw in the AMS science working document reproduced earlier) that there ought to be no conflict/contradiction between science and religion:

*'Science is the quest for truth through investigation. The study of religion is finding The Truth through His words. There should be no contradiction.'*

A realist position of truth is adopted involving a belief in the existence of postulated entities as an independent reality. This, despite the fact that the majority of physicists have become convinced that quantum uncertainty is something deeper than merely a matter of observation and measurement. When we measure precisely a particle's momentum, that particle does not at the moment of our measurement have any definite position to be measured.

That raises the question of whether anything that is not located somewhere is a real 'thing'. Does it actually exist as an independent entity? Muslim science teachers were not prepared to contemplate these questions, exhibiting complacency in their professed certainties and conceptions of absolute truth.

The prospect of quantum uncertainty was disturbing for science teachers determined to connect the certainty of religious belief with the 'certainty' of scientific theory. The prospect of a world with no concrete reality, where only under observation an atom resolves itself into either an atom with a location or an atom with a definite momentum, apparently did not fit in with their deterministic conceptions. As one respondent commented:



*'Einstein said that God does not play dice with the universe. This is true; Allah knows everything; the physical world is Allah's creation and hence science is about certainty.'*

There is, therefore, an apparent contradiction in the Muslim science teachers' perception of science and the proposition that the observer seems to create reality by observing it.

At one level it is possible to understand the Muslim science teachers' conceptual problem (although from my interviews and observations he/she is unlikely to have thought of this). In a parallel line of thought, we could pose the question: can God exist without believers? Would belief create an affirmative answer to the question 'Is there a God?', just as observation may create an affirmative answer to the question 'Do subatomic particles exist?' One could not say that the believer is deluded any more than one cannot say that a physicist who locates an electron at a definite position is deluded.

But we see the problems for the Muslim science teacher - and perhaps for science teachers in general. Most of us feel instinctively that there is a definite answer to every question (although Muslim science teachers claim they 'know' there are definite answers due to their belief in an Omniscient Creator), even the question of whether God exists. We feel that our opinions and our beliefs do not make something real or unreal. When it comes to decisions about ultimate reality, quantum level hints to the contrary do not customarily play a significant role.

Muslim science teachers believe that there is ultimate truth beyond physical and mathematical explanation. That our self-awareness, our minds, personalities, intuitions, and emotions cannot be entirely accounted for by means of a physical explanation. Science is not in a position to assimilate these phenomena into the materialistic picture. Yet in Muslim science education scientific findings are casually taken and made sense of in the light of Quranic verses.

The ‘truth’ of scientific explanation is consistently juxtaposed with the Truth beyond the range of scientific explanation. Both ‘certainties’ are taught in the classroom which is probably a recipe for intellectual confusion amongst pupils. This is certainly a fertile area for further research: the perceptions Muslim students taught in Muslim schools by Muslim science teachers, have of scientific theories interpreted in an absolutist way in the context of remotely related Quranic statements. How do their perceptions affect their attitude to science-Technology-Society issues? What impact do these student-perceptions have on their responses to examination questions? Are they radically different to the perceptions of students taught science in the context of other faiths and, indeed, to the perceptions of students espousing no faith at all?

#### 8.11 The Nature of Science in the National Curriculum

One very obvious and practical reason for considering the nature of science is the fact that it is present in the National Science Curriculum. At Key Stages 3 and 4, the understanding of the nature and history of scientific ideas is considered to be an essential element in the study of science. This element seems to have three essential components:

1. the idea of the limits of science, i.e. it is not the only way of understanding experience;
2. the study of changes in scientific ideas over time and across cultures;
3. the importance of the context of science, moral, spiritual and cultural; the idea that science is a cultural activity.

These components - limits, changes and context - are present in both the general programmes of study and the programme for Sc1 (Experimental and Investigative science), (though unfortunately not in the remaining three attainment targets). Thus the PoS for KS3 requires that students should consider the ‘benefits and drawbacks of applying scientific and technological ideas’ and that they should begin to understand ‘how science shapes and influences

the quality of their lives' (limits and context). They should also develop their knowledge of how 'scientific ideas change through time' (changes). In the PoS for Sc1, students should be given 'opportunities to understand the limitations of scientific evidence and the provisional nature of proof' (limits again). At KS4 the requirement to study the change of scientific ideas through time is repeated (change). The way in which the use made of science is affected by its social, moral, spiritual and cultural contexts is also added at this level (context). Students should also examine 'the power and limitations of science in solving industrial, social and environmental problems' (limits). The PoS relating to Sc1 requires that students should explore the nature of science and be able to 'distinguish between claims and arguments based on scientific considerations and those which are not' (limits) and that they should study examples of scientific controversies and the way in which scientific ideas change. Teachers are required to include these components in their courses and schemes of work; hence the need for teachers to consider their own view of the nature of science. As Shuell puts it, perhaps rather forcefully:

"The conceptions and assumptions we hold about the nature of knowledge, the way knowledge is represented and the manner in which new knowledge is acquired determines what we study in science education, what we teach in science classrooms and the way in which the teaching of science is carried out." (Shuell, 1987, p.35)

That is to say, the teacher's own image or view of what science is does have implications for the way that they present and teach science in the classroom. The problem, however, arises in trying to pin down a particular view of science into a pre-determined philosophical category - be it relativist/positivist, inductivist/deductivist, contextualist/decontextualist, instrumentalist/realist. In any case it is not necessary, as the present thesis shows, to categorise the views of teachers in order to take account of them.

One of the messages that runs through the PoS of the NC is that scientific knowledge is provisional, i.e. its ideas, laws and theories are subject to change. This is even more true of

views on the nature of science. There is no general consensus on what science is, neither is there a commonly agreed view of what constitutes 'scientific method'. Many people argue that the way science is viewed and conceptualised varies from one discipline to another, for example, from life science to physical science (Lederman, 1992). There is certainly a wide variation in view amongst well-known philosophers on the nature of science, ranging from Popper (1959) and Kuhn (1963) to the late Feyerabend (1975), with the latter arguing against the idea of there being any such thing as scientific method. There is, in short, no single fixed view of what science is, or of what constitutes scientific method. The problem is that most science teachers think there is a method, and some teachers think that science is a pursuit of truth, and hence they marginalise or do not appreciate their own attitudes and views, implicit or otherwise.

Hence, it makes no sense to accuse teachers of having an inadequate conception of science, nor to berate them for it (see, for example, Lederman 1992). What can be expected of teachers, however, (regardless of religious or ideological background) is that they do recognise in their teaching that science as a body of knowledge is provisional and that there is no single accepted view of scientific method. Teachers should also emphasise that science and technology are not neutral or value-free activities. Science is pursued within the context of a culture or society with its own economic and political pressures and constraints. In short, conceptual categorisation is not the central issue, but raising awareness about the nature of science is.

Having raised these points, it should perhaps be pointed out that there is still much in the Programme of Study at both KS3 and KS4 which facilitates, and to some extent demands, the teaching of science in the broad mode which is undoubtedly essential.

No-one thinks that teaching such aspects of science is easy. It is not easy because, in part, of the importance attached to summative assessment through aid of KS3, SATIS, GCSE and

league tables. But difficulty is hardly an adequate reason for not trying. What is now required is serious work on how best to incorporate these complex yet crucial matters into our day-to-day teaching of science. This is a central task for Muslim science teachers teaching in Muslim schools.

The 'Review of Qualifications for 16-19 Year Olds' (March 1996), the latest Dearing Report, makes many comments and recommendations. In the chapter entitled "Unlocking potential' there is a significant section which has received little comment:

"The spiritual and moral dimension of 16-19 education

7.7 Maintained schools have a legal responsibility to provide for the spiritual, moral and cultural development of pupils, and are required to provide religious education for all, including those in the sixth form. While further education, sixth form colleges and training providers have no legal requirement to promote spiritual and moral development, these are no less relevant for their students. The spiritual and moral dimensions should be taken into account and consciously included in the curriculum and programmes of young people, and wherever possible in the design and approval of qualifications.

7.8 Spiritual and moral development has a double focus, intellectual and personal. Intellectually, young people increasingly encounter issues and experiences which raise questions of a spiritual or moral nature. These questions will frequently need resolving, often leading to action at home or in the workplace. Secondly, spiritual and moral development is integral to personal growth to adulthood. It includes care for and appreciation of the natural world, the wish to know and understand, a sense of awe and wonder, sometimes even at the simplest everyday things.

7.9 Such concerns transcend what can be achieved through qualifications alone, although these have their part to play in heightening awareness of such issues." (Dearing, 1996)

Recommendations

- Regulatory and awarding bodies should recognise the potential relevance of spiritual and moral issues to individual subjects, particularly when designing and approving syllabuses.

- All providers of education and training should take spiritual and moral issues into account in the design and delivery of the curriculum and programmes for young people.

“Care for and appreciation of the natural world, to wish to know and understand, a sense of awe and wonder” all seem highly relevant to the teaching of science, even though they have sometimes been neglected. From the Muslim point of view (and perhaps that of other religious traditions), if they were made a part of all science courses, not only at 16-19, that would be a major step forward in humanising the teaching of science and may help to motivate pupils.

#### 8.12 Concluding Remarks

Much of Muslim school science is about acquiring knowledge and skills in the context of an absolutist theological dimension. Concerned as it is with facts and principles, it has failed to engage many students and has little meaning for the lives of the majority outside school. It has failed to help students develop an independence of mind and has not prepared them for the society in which they live. Many Muslim students will encounter science through the media in the form of the issues it raises, but they will also encounter it directly in the way it shapes their social and economic lives. They must acquire the skills to recognise science in its applications to economic, sociological and political issues. When they leave school they will be faced with opposing views. It is necessary for them to learn to explore their own views and those of others in order to develop an independent way of thinking. As a result of finding out more about themselves they will become more self-confident. They will acquire an understanding of bias and partiality of evidence and be willing to consider and be sensitive to the opinions of others.

Science is often presented to students in Muslim schools in a way that makes it seem unproblematic. The Muslim science teacher 'knows' all the answers - including the theological or metaphysical context. Sensitive controversial issues in science are not discussed, yet by discussing such issues we are helping to modify the students' image of science towards a more realistic understanding.

There are many ways of approaching the teaching of sensitive issues, but if one is to guard against indoctrination, certain pedagogies would not be considered. A didactic style - the situation pertaining in most such schools - would be quite inappropriate. The approach should foster autonomy and critical awareness. It should renounce the authority of the Muslim science teacher as the 'expert' capable of solving value issues by a quick and ready reference to the Quran. The idea of a neutral chairperson who facilitates the students' exploration of the issue is a novelty for Muslim schools. At the moment, arguments are won by citing references to the Quran which in many cases are of remote relevance to the context. Evenhandedness of STS discussions is jeopardised by an incessant one-dimensional interpretation of issues and events. It is essential to develop broader insights.

Information is acquired by considering evidence which should provide insights into other people's points of view and perspectives on life. The evidence may be presented as television broadcasts, video recordings, interviews or printed materials. Discussion, with students working in groups, is the ideal pedagogy. However, if Muslim schools are to aim for active student participation some restructuring will be required. This will encourage student involvement, provide an opportunity to practise the social skills of communicating and collaborating and help to develop co-operative group work skills. This is an area where extensive research is required in Muslim schools.

Muslim science teachers (from the sample studied) were overprescriptive in their enthusiasm to get across the monotheistic message through their science teaching. Through my interviewing and observations I did not find that there was any awareness of wider religion and science education issues. They operated in the parochial confines of a fundamental Islamic perspective.

There is no comparable organisation in the Muslim teaching community as CISE (Christians in Science Education) in the Christian community. Hence, there is no suitable vehicle, at the moment, for raising the awareness amongst Muslim science teachers of wider religion and science education issues - the thesis, for instance, argued by Mahner and Bunge (1996) that '(1) Science and religion are incompatible, (2) a religious education ... is an obstacle to the development of a scientific mentality, (3) and that therefore we should only teach our children how science explains the existence of religion in historical, biological, psychological and sociological terms' (Mahner & Bunge, 1996).

Michael Poole in the same journal (1996) has provided an eloquent rejoinder to these confident assertions and Muslim science teachers would, in my judgement, benefit from his contribution. At the moment, however, the religious imperialism of most Muslim science teachers is an impediment to getting to grips with the logical positivist scientific imperialism of writers like Mahner and Bunge.

Training programmes in discussing nature of science themes are therefore essential for Muslim science teachers teaching in Muslim schools where, at the moment, epistemological narrow-mindedness constrains broad-minded scientific development in young children. (Again, video-taped recordings of lesson observations provide ample evidence of this strait-jacketed approach.) Muslim science teachers showed lack of awareness of efforts to replace older



conceptions of scientific method, which focused on its inductivist and empiricist traditions, with more modern conceptions. As comments quoted throughout this chapter show, they were oblivious of newer ideas about the nature of scientific investigation that have emphasised the social construction of knowledge, the importance of teaching processes within a context of relevant concepts, and a view of the scientist as emotional and involved rather than coldly objective and detached. Muslim science teachers continue to sail in the transcendental seas of Muslim school science where the metaphysical objective is glorification of the Creator - unperturbed by crucial developments in the nature of science and how they affect the teaching of science in Muslim schools. This thesis has built up a body of evidence to uphold this view.

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## **APPENDIX**

### **DEVELOPMENT OF SUPPLEMENTARY SCIENCE TEACHING MATERIALS IN MUSLIM SCHOOLS: A WAY FORWARD?**

This is a scheme developed by the present author on behalf of the Association of Muslim Schools. It is a skeletal framework which needs to be 'fleshed out' before implementation. It is based on the old Attainment Target 17 (The Nature of Science) and two of the National Curriculum cross-curricular themes - Health Education and Environmental Education.

The approach adopted is one that presents science more realistically (in my judgement) through teaching the history of scientific discovery (with particular emphasis on scientific discovery in Muslim civilisation). To study how scientific knowledge has actually been generated is to see the process of science in action. Students can observe from these studies the role that is played by intuition, religious belief and hard work, and see that there is no simple formula (like belief in God) that guarantees successful discoveries in science.

TITLE OF TOPIC	HEADING AND NO OF EACH CARD	FURTHER DETAILS OF CARD SUB-TOPIC	LINKS WITH SCIENCE CURRICULUM AND/OR CROSS-CURRICULAR THEMES
FOOD AND DRINK (including drugs and alcohol)	1. Dietary Regulations in Islam	The reasons for certain prohibitions. Firstly, as commands from God; secondly, medical and biological reasons.	<b>Health Education: KS4 Food and Nutrition</b> 'Know that various types of diet promote health for different groups, acknowledging cultural and ethnic variations.'
	2. Food Additives	Explanation of the E-code in relation to all types of food additives in the context of the Food Labelling Regulations of 1984. Discussion of some of the effects of food additives.	<b>Health Education KS4 Food and Nutrition</b> 'Understand consumer aspects of food hygiene; shopping for food; legislation, including the current food labelling system.'
GCSE 1	3. Alcohol	A statistical-analytic approach. Discussion of the social/biological effects of hard drugs and alcohol. Integrated with the Islamic approach	<b>Health Education KS4 solvent use and misuse</b> All attainment targets relevant. <b>Science AT3 Processes of Life Level 6</b> '...understand the risks of alcohol, solvent and drug abuse and how they affect body processes.'
4 cards	4. Drugs	A statistical-analytic approach. Discussion of the social/biological effects of hard drugs and alcohol. Integrated with the Islamic approach	<b>Health Education KS4 solvent use and misuse</b> All attainment targets relevant. <b>Science AT3 Processes of Life Level 6</b> '...understand the risks of alcohol, solvent and drug abuse and how they affect body processes.'

TITLE OF TOPIC	HEADING AND NO OF EACH CARD	FURTHER DETAILS OF CARD SUB-TOPIC	LINKS WITH SCIENCE CURRICULUM AND/OR CROSS-CURRICULAR THEMES
POLLUTION AND THE ENVIRONMENT  GCSE 2	1. Islam's view of the Environment	Discussion of the environmental problems from the Islamic perspective, and how such an ethical perspective is relevant for contemporary times.	<b>Science AT17 The Nature of Science Environmental Education The Green Belt Issue</b> '... encourage pupils to examine and interpret the environment from a variety of perspectives - geographical, sociological, economic, political, technological, historical, aesthetic and ethical.'
	2. Common Examples of Pollution	Description of nature and effects of specific pollutants such as sewage, oil slicks and smog.	<b>Science AT5 Human Influences on the Earth Level 5</b> '...be able to describe the sources, implications and possible prevention of pollution.'
	3. Acid Rain and the Greenhouse Effect	An analysis of the causes and effects - local and global - of these two hotly debated environmental issues	<b>Science AT5 Human Influences on the Earth Level 9</b> '...understand the basic scientific principles associated with a major change in the biosphere, for example, <u>destruction of the ozone layer</u> , <u>'the greenhouse effect'</u> .'
	4. The Work of Environmental Groups	Discussion of the activities of Greenpeace and Friends of the Earth in helping to bring about a change of attitude and action on environmental issues.	<b>Science AT5 Human influences on the Earth Level 10</b> '...be able to select and weigh evidence to form reasoned judgements about some of the major ecological issues facing society.' <b>Also = Levels 5 and 7</b> <b>Education for Citizenship: Democracy in Action</b> '...the roles and aims of trades unions, professional associations and pressure groups.'

OF TOPIC	HEADING AND NO OF EACH CARD	FURTHER DETAILS OF CARD SUB-TOPIC	LINKS WITH SCIENCE CURRICULUM TITLE AND/OR CROSS-CURRICULAR THEMES
NUCLEAR POWER GCSE 3 4 CARDS	1. Nuclear energy: fission and fusion processes	Explanation of how nuclear energy is utilised in nuclear fission and fusion reactors. The mammoth Joint European Torus (JET) project is given a special emphasis.	<b>Science AT13 Energy</b> '...be able to describe in outline how electricity is generated in power stations, including fossil fuels, nuclear fuels and renewable energy resources.'
	2. Atomic weapons	Methods and problems associated with nuclear waste disposal. Distinction between atomic weapons and fission and fusion based nuclear reactors.	<b>AT13 Energy Level 10</b> '...be able to evaluate the various costs and benefits of different energy sources and appreciate that society needs to take these into account before making appropriate decisions on policy.'
	3. Disposal of Nuclear Waste	Methods and problems associated with nuclear waste disposal. Distinction between atomic weapons and fission and fusion based nuclear reactors.	<b>AT13 Energy Level 10</b> '...be able to evaluate the various costs and benefits of different energy sources and appreciate that society needs to take these into account before making appropriate decisions on policy.'
	4. Nuclear Power: the moral dimension	Exploring the moral aspects of nuclear power from a religious (Islamic) perspective. Including also the moral and ethical arguments of environmental secularists.	<b>KS4 Extract from the Programme of Study for Science</b> '...they should begin to understand the power and the limitations of science in solving industrial, social and environmental problems.' <b>Education for Citizenship: Attitudes</b> '...independence of thought on social and moral issues', '... respect for different ways of life, beliefs, opinions and ideas'.



TITLE OF TOPIC	HEADING AND NO OF EACH CARD	FURTHER DETAILS OF CARD SUB-TOPIC	LINKS WITH SCIENCE CURRICULUM AND/OR CROSS-CURRICULAR THEMES
HUMAN REPRODUCTION GCSE 4 3 CARDS	1. Human Reproduction in the Qur'an	Discussion of the remarkable accuracy of Qur'anic statements about human reproduction, which were free from the unfounded myths that prevailed in a significant segment of the world for a millennium.	<b>Science AT17 The Nature of Science</b> '...be able to explain how a scientific explanation from a different culture or a different time contributes to our present understanding.'
	2. Early ideas of Human reproduction	Early Greek/Aristotelian ideas. The work of William Harvey. The concepts of preformation and epigenesis.	<b>Science AT17 The Nature of Science</b> '...be able to demonstrate an understanding of the differences in scientific opinion on some topic, either from the past or present, e.g. living things reproduce their own kind and the spontaneous generation of species.'
	3. Basic concepts of Human reproduction	The function of sexual organs and the development of the child in the womb. Human reproduction from a purely biological perspective.	<b>Health Education KS4 Sex Education</b> '...understand the biological aspects of reproduction.'

TITLE OF TOPIC	HEADING AND NO OF EACH CARD	FURTHER DETAILS OF CARD SUB-TOPIC	LINKS WITH SCIENCE CURRICULUM AND/OR CROSS-CURRICULAR THEMES
CONTRACEPTION, ABORTION AND INVITRO FERTILISATION  GCSE 5  6 CARDS	1. Abortion, the Islamic point of view.	A look at a variety of situations in which abortion would or would not be permitted and why.	<b>Health Education KS4 Family Life Education</b> '...know about the technology available to help in the reproductive process and be able to discuss the ethical, moral and legal issues involved.'
	2. The Biology of Abortion	Discussion of various methods of and contraception, including definitions, common methods of invitro-fertilisation.	<b>Health Education KS4 Family Life Education</b> '...know about the technology available to help in the reproductive process and be able to discuss the ethical, moral and legal issues involved.'
	3. Contraception, the Islamic point of view.	Discussion of contraception and invitro-fertilisation in the context of Islamic concepts. constructing scenarios to clarify the debate. Including a section on surrogate motherhood and its ethical implications. Study of extracts of writings, reports (of the Warnock Committee on Human Fertilisation and Embryology) and letters in connection with issues such as abortion, contraception, surrogate motherhood, embryo research, etc.	<b>Health Education KS4 Sex Education</b> '...recognise and be able to discuss sensitive and controversial issues such as conception, birth, HIV/AIDS, child rearing, abortion and technological developments which involve consideration of attitudes, values, beliefs and morality.'

CONTRACEPTION, ABORTION AND INVITRO FERTILISATION	4. The Biology of Contraception	Discussion of various methods of abortion and contraception, including definitions. common methods of invitro-fertilization.	<b>Health Education KS4 Family Life Education</b> '... know about the technology available to help in the reproductive process and be able to discuss the ethical, moral and legal issues involved.'
	5. Invitro- fertilisation: the Islamic viewpoint	Discussion of contraception and invitro-fertilization in the context of Islamic concepts. constructing scenarios to clarify the debate. Including a section on surrogate motherhood and its ethical implications. Study of extracts of writings, reports (of the Warnock Committee on Human Fertilisation and Embryology) and letters in connection with issues such as abortion, contraception, surrogate motherhood, embryo research, etc.	<b>Health Education KS4 Sex Education</b> '...recognise and be able to discuss sensitive and controversial issues such as conception, birth, HIV/AIDS, child rearing, abortion and technological developments which involve consideration of attitudes, values, beliefs and morality.'
	6. The Biology of invitro- fertilisation	Discussion of various methods of abortion and contraception, including definitions. common methods of invitro-fertilization.	<b>Health Education KS4 Family Life Education</b> '... know about the technology available to help in the reproductive process and be able to discuss the ethical, moral and legal issues involved.'

TITLE OF TOPIC	HEADING AND NO OF EACH CARD	FURTHER DETAILS OF CARD SUB-TOPIC	LINKS WITH SCIENCE CURRICULUM AND/OR CROSS-CURRICULAR THEMES
BIOTECHNOLOGY AND GENETIC ENGINEERING  GCSE 6  4 CARDS	1. The Ethics of Genetic Engineering engineering.	Social and ethical issues regarding the recent developments in genetic Mammalian gene transplants, DNA fingerprinting in humans, and cloning. The Islamic perspective.	<b>Science AT4 Genetics and Evolution Level 10</b> ‘... be able to make informed judgements about the economic, social and ethical issues concerning the recent developments in genetic engineering.’ <b>Education for citizenship: being a citizen</b> ‘... the duties, responsibilities and rights of individuals and societies.’
	2. Biotechnology in industry	Examples of biotechnological processes in industry such as the making of bread, yoghurt, Single Cell Protein, and sewage treatment works.	<b>Science AT5 Human Influences on the Earth</b> <b>Environmental Education - Use of biological resources</b>
	3. Introduction to Genetic Engineering.	Theoretical features of genetic engineering. The biological basis of inheritance, explanation of Recombinant DNA, DNA ligase and nuclease enzymes.	<b>Science AT4 Genetics and evolution, Level 8</b> ‘...be able to describe examples of the inheritance of human genetic diseases.’ <b>Level 10</b> ‘...understand how DNA replicates itself and controls protein synthesis by means of a base code.’
	4. Examples of Genetic Engineering: from bacteria to Man	Examples include nitrogen fixation, hormone production, antiviral agents (interferon) and cloning methods.	<b>Science AT4 Genetics and Evolution Level 10</b> ‘...understand the basic principles of genetic engineering in relation to drug and hormone production.’

## MAIN TOPIC: THE NATURE OF SCIENCE

### WORKCARD SUBTOPIC: CAUSE AND EFFECT IN SCIENTIFIC INVESTIGATION

Science works, in the main, by producing definite ideas (or **hypotheses**) about the physical or biological world, and then testing them through experiments and observations. This process enables evidence to be built up which can then be used to accept or reject the **hypothesis**.

Scientists, of course, like everyone else, make mistakes and have flashes of inspiration. So it is not difficult to find examples which contradict the image of scientists as single-minded people, all working in exactly the same way. They do, nevertheless, in the way they practise their science, have some things in common that bind the community together. One of the central things here are cause and effect relationships.

Illustration of a scientist having a flash of inspiration.

Consider a Martian who arrives on Earth and, after a year of close observation, concludes that because policemen are almost always seen around the scenes of criminal acts, they are responsible for them. We know, of course, that the Martian is wrong. He or she has been misled by the clustering together of crimes and police officer.

Illustration of a Martian arriving on earth

Let us take another example. A farmer may be impressed by the observation that a sheep which feeds on a specific type of vegetation also develops unusually tough wool. He then draws the apparently obvious conclusion that a particular plant has caused the fleece to change. If the sheep are of a new breed that tend to develop tougher wool, then the farmer

is wrong. The two observations that he has connected together are really unrelated. That is, there is no **causal relationship** between them.

The basic mistake behind the thinking of the Martian and the farmer is the same. They are observing a close relationship between two events, A and B, and applying common sense to conclude that A causes B. It is not that simple, however. It may be that B causes A, or that both A and B result from a third factor, C, which may not as yet be identified. A real life example may shed more light on this.

For many decades there was a great dispute about the link between cigarettes and lung cancer. Doctors began to realise that the disease was commoner among smokers, and even more so amongst those who smoked a large number each day. The connection between cigarette smoking and lung cancer therefore seemed obvious. But it could have been wrong. There could have been a third factor - certain individuals may have had a genetic tendency both to smoke and to develop lung cancer. Things were not that simple.

Slides showing effect of tobacco on lungs.
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Only during the 1950s did a painstaking study of smoking patterns make the common sense conclusion very hard to resist. It was shown that those individuals who gave up the habit carried a reduced risk of contracting cancer. Also, increased smoking with increased lung cancer was observed among women, who began later than men in most countries.

A word of warning is necessary here. Not **all** things can be explained on the basis of *cause and effect*. *In modern physics it is now realised that in the subatomic world, matter and energy behave in a more bizarre fashion.*

Slides showing the effects of subatomic particles.

Their behaviour cannot be described so simply. This, perhaps, can give us some idea of the nature of Allah, whose existence cannot be explained by the human notions of cause and effect. Everything else is dependent on Him, and He is independent of everything. The Qur'an declares:

*Say: 'He is Allah, the One and Only; Allah, the Eternal Absolute; He begets not, nor is He begotten, and there is none like Him.*

Qur'an 112:1-4

Advances in science can therefore lead to a greater understanding of Allah rather than sowing doubts about His nature and existence.

### Activities

#### 1. Key words

**hypotheses**  
**causal relationship**

**hypothesis**  
**subatomic**

2. Lung cancer can develop in non-smokers and it is sometimes absent in very heavy smokers. How, then, was it possible to establish a link between tobacco and lung cancer?
3. Give your own example of the misleading thinking concerning cause and effect that the Martian and the farmer indulged in, as explained in the text.

4. Newton's third law of motion states: 'Action and reaction are equal and opposite.'

How do you think this statement influenced scientists searching for causes for natural events?

5. Can the origin of man be described in terms of cause and effect relationships? Discuss this problem amongst yourselves.



## **MAIN TOPIC: HUMAN REPRODUCTION AND THE ORIGIN OF LIFE**

### **WORKCARD SUBTOPIC: NATURAL SELECTION OR DESIGN IN CREATION**

**Natural selection** is a theory of the way in which **evolution** of life takes place. It was first put forward by the nineteenth century biologist **Charles Darwin** and is often referred to as **Darwinism** or the Darwinian theory. Basically it says that those organisms having the best characteristics for adapting to a particular environment will survive while others will die out. The distinctive characteristics, selected naturally, will be inherited by their offspring so that the **species** begins to multiply and thrive.

Photo of Charles Darwin

Darwin collected a vast amount, and variety, of evidence to support the idea that life evolved by means of natural selection. Yet many people, when admiring the beauty of a peacock's tail, the sensitivity of the eye of a bird of prey, the precision involved in bird migration, or the wonder of human consciousness, still find it hard to believe that these things evolved 'by accident'.

Illustrations of eye, peacock's tail

The argument of design has been used to show that life must have been created. The famous English **theologian** William Paley, for example, (1743-1805), reasoned that if you found a watch, the intricacy of its cogs and springs would show that it must have been designed. The same thing, he argued, applied to the plants and animals on planet Earth.

Photo of William Paley

The British zoologist Richard Dawkins (Oxford University) , who is a firm believer in the Darwinian theory, has argued that the random events of natural selection, i.e. **mutations**, can be creative. In his book, *The Blind Watchmaker* (1985) he considers the amusing notion of whether a monkey, bashing away aimlessly at a typewriter keyboard, would ever produce the works of Shakespeare!

Illustration of a monkey working on a typewriter

This is how this thought game works. Take only one line, 'methinks it is like a weasel', and consider just the first letter. There are 27 letters (a space counts as a letter) in this sentence. Therefore, there is a one in 27 chance that the monkey will get this right the first time. However, the chances of getting the first two letters correct is one in 27 multiplied by one in 27, which is one in 729. If we follow this through, the chance of the monkey getting the entire sentence correct is the incredibly large figure of one in 10,000 million million million million million million ( $10^{39}$ ).

The evolutionists, however, do not suggest that a peacock's tail or an insect's eye were produced by an incredible number of changes that happened all at once. They believe that random changes - mutations - are selected over many generations, over the course of millions of years. The altered organisms are preserved for further stepwise changes as and when there are important changes in the environment.

Illustrations of a reptile evolving into a bird.

Believers in Allah view evolution as a process, and natural selection as a way in which human beings are thought to have arisen. A statement that someone made Man and Woman does not interfere with a statement about

the way it is thought to have occurred. Evolution is the name of a process and is in no way an **ultimate cause**; that is, it does not explain the origin of life and the universe, but only the way in which they progressed after they came into existence.

This does not mean, of course, that believers in Allah as the supreme Creator also believe in the theory of evolution. In fact many of them do not. They believe that species may adapt to different conditions and give rise to a number of **varieties**, but they remain distinct and do not evolve, over time, into a new species. Allah says in the Qur'an:

*Verily, when He (Allah) intends a thing (to happen), His command is 'Be', and it is!*

(Qur'an 36:82)

Slide of mountains and lakes - scenic beauty

## Activities

1. **Key words:** Find their meanings

**natural selection**

**evolution**

**mutation**

**Darwinism**

**species**

**ultimate cause**

**theologian**

**varieties**

2. It is not easy to believe that the beauty of a peacock's tail or the brilliant sensitivity of an eagle's eye arose as a result of random and

purposeless mutations. The odds against an organ such as the eye arising in a single step are many billions of times greater than the number of atoms in the universe. Why, then, do most biologists still believe in evolution? Explain your answer.

3. Richard Dawkins, the Oxford University biologist, has devised a computer programme to show how random changes - mutations - are selected over many generations. In one experiment based on that same line of Shakespeare mentioned in the text ('Methinks it is like a weasel'), the computer chose a totally random sequence of letters. It then 'bred' from this repeatedly, with occasional mistakes (equivalent to mutations) in the copying.. At each stage the computer examined the nonsense phrases and selected the one that was closest to the target sentence. After ten generations, it had produced MDLMDMNL SIRJISWHRZREZMECS P. A further ten generations later, this had become MELDINS IT ISWPRKE Z WECSEL, and after another ten generations the line was METHINGS IT IS WLIKE B WECSEL. By generation 40 it was just one letter short of the target line which was reached in generation 43.

Some people would take this as evidence that life on Earth has risen through evolution and that Allah is not behind its creation and direction. Hold group and/or class discussions on this issue and then explain clearly, in writing, why you agree or disagree with this view. Remember to use good arguments to back up what you say.

4. Is it possible to believe in Allah as the Supreme Creator and, at the same time, in evolution? Are the two things always in conflict? Think carefully about this before you put pen to paper.

## MAIN TOPIC: HUMAN REPRODUCTION AND THE ORIGIN OF LIFE

### WORKCARD SUBTOPIC: THE ORIGIN OF LIFE

In this workcard we shall examine an area where religious belief sometimes clashes with scientific theory - the origin and development of life on Earth.

The view accepted by many biologists is that at one time conditions on Earth were favourable for the appearance of life in a lifeless world. The planet is said to have been covered in a vast **primeval soup**, containing a rich and varied mixture of simple chemicals. Lightning, **radiation** and **volcanic eruptions** enabled further chemical reactions to take place, giving rise to more complex molecules of the sort we now describe as **organic**. These molecules - **amino-acids**, **sugars** and **nucleotides** - are the essential building blocks for life, being associated with **metabolic processes** and living cells. In the course of millions of years, it is argued, mixtures of these substances came together in such a way as to produce units which were able to **replicate** themselves.

Illustration of a vast primeval soup, with lightning and volcanic eruptions

Since the 1950s, scientists have carried out laboratory experiments which have shown that the crucial building blocks of **protein** and **nucleic acid** can be synthesized under the supposed conditions of the early Earth. Moreover, **geological studies** suggest that the planet was in a highly favourable state for the emergence of life.

Such evidence however, is far from conclusive. Indeed, debates about the origin of life continue to rage among biologists. For several; decades the **primeval soup hypothesis** was accepted almost without question.

Alternative explanations, however, have now been put forward. One such theory is **panspermia**, put forward by the astronomers Fred Hoyle and Chandra Wickramasinghe. They argue that organic molecules are stored away inside **comets**, which shed this material when closest to the Sun (in the region of the Earth). The frozen bacteria and organic molecules thaw at the comet's surface and some of them fall to the Earth. Here they 'take root' in favourable surroundings.

Slides of comets in space

This approach does not, of course, answer the question of the actual way in which life arose on our planet, but merely moves the event to another location at another time. Religious believers do not have such uncertainty when it comes to the origin of life. They believe that life on Earth is an act of special divine creation. Allah says in the Qur'an:

*It is He who has created for you all things that are on Earth; moreover, His design comprehended the heavens. ... And of all things He has perfect knowledge.*

Qur'an 2:29

Slide of the Milky Way Galaxy and solar system

Many biologists feel that there is no need for this sort of explanation for the origin of life. They are content with the uncertain evidence which they claim supports the theory that living, organic matter arose from dead, inorganic matter, without any divine intervention. Believers, however - and this includes believers who are scientists - continue to believe in special

creation by Allah - the one and only universal God of all humanity. Their faith is such that they would remain firm in their belief even if human experimenters were to create real, self-reproducing cells in the test-tube. They could argue that scientists had simply learned how to copy Allah's handiwork.

*Not for (idle) sport did We (Allah) create the heavens and the earth and all that is between.*

Qur'an 21:16

Slide to show interstellar matter

### Activities

1. Key words: find the meanings.

**primeval soup**

**metabolic processes**

**radiation**

**replicate**

**volcanic eruptions**

**proteins**

**organic**

**nucleic acid**

**amino acids**

**geological studies**

**sugars**

**panspermia**

**nucleotides**

**hypothesis**

**comet**

2. In your view, is life on Earth an act of special divine creation or did it arise out of 'nothing'? Explain your answer.
3. Many scientists who are non-believers refer to the random nature of the processes upon which all life depends. This viewpoint is expressed in the book *Chance and Necessity* by the French biologist Jacques Monod (1910-1976), who shared a Nobel Prize in 1965. According to Monod, there is pure chance, free and blind, at the root of evolution,

and man emerged only by chance. Not all biologists would agree with this view. Do you? Explain why.

4. The original 'panspermia' theory was put forward in 1907 by the Swedish chemist Arrhenius. He proposed that living cells are generated in space, and that these spores travel between stars until some fall on Earth. Do you find this theory convincing? Explain why.
5. Produce a poster entitled 'The Origin of Life' explaining, with the aid of relevant diagrams and photographs, how you believe life arose on this planet. You will need to consult books in the library as well as some of your teachers for this project.